CENTRAL VALLEY REGIONAL
WATER QUALITY CONTROL BOARD

PROPOSED AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE SACRAMENTO RIVER AND SAN JOAQUIN RIVER BASINS

FOR

THE CONTROL OF PYRETHROID PESTICIDES DISCHARGES

EXCERPT ON ALTERNATIVES CONSIDERED AND RECOMMENDATION FOR WATER QUALITY OBJECTIVES
CHAPTER 5 AND APPENDIX C

MAY 2015

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

EXCERPT FROM THE DRAFT STAFF REPORT RELATED TO ALTERNATIVES CONSIDERED AND RECOMMENDATIONS FOR PYRETHROID WATER QUALITY OBJECTIVES PROTECTIVE OF AQUATIC LIFE

The following chapter is an excerpt from the draft staff report that provides the rationale for the proposed amendments to Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the control of pyrethroid pesticides discharges. The entire draft staff report was submitted for external scientific peer review on May 29, 2015.

Chapter 5 and Appendix C of the report are being released separately prior to completion of the external scientific peer review to provide preliminary information to the public on the technical analysis supporting development for a portion of the proposed amendment. Chapter 5 describes the alternatives considered and the staff recommendation for water quality objectives for pyrethroid pesticides. Appendix C includes data used for the technical analysis given in Chapter 5. The preceding and subsequent chapters and appendices of the report, which are not the focus of the scientific peer review, are not being released at this time. A complete draft staff report will be released for public comment after the peer review comments have been received and responses to those comments have been prepared (estimated release in winter 2015).

Information regarding this project can be found at:
http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/central_valley_pesticides/pyrethroid_tmdl_bpa/index.shtml

LIST OF ACRONYMS AND ABBREVIATIONS

§	Section
μg/L	Micrograms per liter (0.1μg/L = 100 ng/L)
ACR	acute to chronic ratio
avg	Average
Basin Plan	Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
CCC	Criterion Continuous Concentration
CDPR	California Department of Pesticide Regulation
CDFW	California Department of Fish and Wildlife
Central Valley Water Board	California Regional Water Quality Control Board – Central Valley Region
CFR	Code of Federal Regulations
CMC	Criterion Maximum Concentration
CRWQCB-CVR	California Regional Water Quality Control Board – Central Valley Region
CWA	Federal Clean Water Act
CWC	California Water Code
Delta	Sacramento-San Joaquin Delta
ESA	Endangered Species Act
K_{DOC}	Dissolved organic carbon-water partition coefficient
K_{OC}	Organic carbon-water partition coefficient
lbs	Pounds
ng/L	Nanograms per liter (100 ng/L = 0.1μg/L)
OPP	USEPA Office of Pesticide Programs
Porter-Cologne	Porter-Cologne Water Quality Control Act
State Water Board	State Water Resources Control Board
TMDL	Total Maximum Daily Load
UC Davis	University of California, Davis
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Water Code	California Water Code
WQC	Water Quality Criteria
WQO	Water Quality Objective

5 WATER QUALITY OBJECTIVES

Water quality objectives adopted by the Central Valley Water Board must protect the beneficial uses designated for the applicable water bodies, and be consistent with state and federal regulations.

Section 303(c) of the Clean Water Act requires states to adopt water quality standards to protect public health and enhance water quality. Water quality standards consist of the beneficial uses of a water body, water quality criteria designed to protect those uses, and antidegradation policies to maintain and protect water quality. Individual states are responsible for reviewing, establishing, and revising water quality standards. Those water quality standards are then submitted to USEPA for approval. In California, the State Water Resources Control Board (State Water Board) and the Regional Water Quality Control Boards are responsible for developing water quality standards. Upon approval by the Central Valley Water Board, State Water Board, State Office of Administrative Law, and USEPA, water quality criteria are incorporated into the appropriate Basin Plan as water quality objectives.

Based on our current body of knowledge, aquatic life habitat uses (WARM and/or COLD) appear to be the beneficial use that is most sensitive to pyrethroids. The definition of freshwater habitat beneficial uses contained in the Basin Plan (page II-2.00) is: “Uses of water that support warm (cold) water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.” Any methodology used to derive water quality objectives must protect the beneficial uses (40 C.F.R. §131.11(a)).

5.1 Pesticides Water Quality Objectives Currently in the Basin Plan

Water quality objectives can be either numeric or narrative. The Basin Plan currently does not include specific numeric water quality objectives for pyrethroids, but contains the following narrative water quality objectives that are applicable to pyrethroid pesticides (page III-6.00):

> “No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses.
>
> Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses.
>
> Pesticide concentrations shall not exceed those allowable by applicable antidegradation policies.

> Pesticide concentrations shall not exceed the lowest levels technically and economically achievable."

The Basin Plan also contains a narrative water quality objective for toxicity that applies to toxicity caused by pesticides, specifying the following (pages III-8.01-9.00):

> "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, and biotoxicity tests of appropriate duration or other methods as specified by the Regional Water Board.
>
> The Regional Water Board will also consider all material and relevant information submitted by the discharger and other interested parties and numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency, and other appropriate organizations to evaluate compliance with this objective."

The Implementation chapter of the Basin Plan includes the following policies for evaluating pesticides relative to narrative water quality objectives (page IV-35.00):

> "For most pesticides, numerical water quality objectives have not been adopted. USEPA criteria and other guidance are also extremely limited. Since this situation is not likely to change in the near future, the Board will use the best available technical information to evaluate compliance with the narrative objectives. Where valid testing has developed 96 hour LC50 values for aquatic organisms (the concentration that kills one half of the test organisms in 96 hours), the Board will consider one tenth of this value for the most sensitive species tested as the upper limit (daily maximum) for the protection of aquatic life. Other available technical information on the pesticide (such as Lowest Observed Effect Concentrations and No Observed Effect Levels), the water bodies and the organisms involved will be evaluated to determine if lower concentrations are required to meet the narrative objectives."

In addition to the Basin Plan's narrative water quality objectives for pesticides and toxicity and associated policies for implementing those objectives, the State Water Board's "antidegradation" policy for maintaining high quality waters (Resolution 68-16) requires the maintenance of existing water quality, unless a change in water quality would provide maximum benefit to the people of the state and will not adversely affect beneficial uses.

Pyrethroids have been identified as causing impairments in the water column as well as in sediments. These two matrices are separated when evaluating data and they will also be considered separately for examination of possible alternatives for water quality objectives. Although they are called “water quality objectives,” they may also apply to sediments because objectives are designed to protect the entire aquatic ecosystem, including maintaining chemical, physical and biological integrity of waters. The water quality objective alternatives for pyrethroids are described in the following sections for 1) aqueous concentrations and 2) sediment concentrations. Numeric water quality objectives could be proposed for just one of the matrices or for both matrices.

5.2 **Additive Toxicity**

Pyrethroids can co-occur in the environment and appear to have approximately additive toxic effects (Trimble et al. 2009, Werner and Moran 2008). All pyrethroids have the same general toxicological mode of action, which is that they bind to and prolong the opening of voltage-dependent ion channels, causing convulsions, paralysis, and death (Brander et al. 2009). There are some variations in the specific symptoms of toxicity among the pyrethroids, particularly between the type I pyrethroids (i.e., those lacking an alpha-cyano group, e.g., permethrin and bifenthrin) and type II pyrethroids (i.e., those with an alpha-cyano group, e.g., cyfluthrin, cypermethrin, esfenvalerate, and lambda-cyhalothrin).

Mixtures of pesticides with the same or similar toxicological mode of action are generally considered to follow the concentration addition model of joint toxicity (Lydy et al. 2004, Olmstead and LeBlanc 2005, PapeLindstrom and Lydy 1997). In the concentration addition model, the concentrations of each pesticide in a given mixture are normalized so that they can be added together (Lydy et al. 2004). Typically the concentrations are normalized to a toxicity reference value, such as an LC_{50} or EC_{50}. The normalized concentrations are added together to result in the total toxicity of the mixture relative to the reference values. The toxic unit approach is the most common way to express the concentration addition model:

Equation 1

$$\sum_{n}^{i=1} \frac{C_i}{ECx_i} = TU$$

where:
C_i = concentration of the i^{th} chemical in the mixture;
EC_{xi} = concentration of the i^{th} chemical that elicits the same response (x) as the full mixture;
TU = toxic unit.

Several studies have demonstrated that the toxicity of pyrethroid mixtures is approximately additive, as predicted by the concentration addition model. Barata et al. (2006) tested mixtures of λ-cyhalothrin and deltamethrin with *Daphnia magna.* Most of the observed effects for survival were within a factor of two of the effects predicted by the concentration addition model. The researchers observed slight antagonism in several of the mixtures and they attributed this to a few unexpected extreme values for joint survival effects. Antagonism means that the combination was less toxic than expected based on the concentration addition model prediction.

Brander et al. (2009) tested mixtures of cyfluthrin and permethrin with *Hyalella azteca* and reported that mortality predicted by the concentration addition model was within a factor of 1.5 or less compared to the toxicity test results. The concentration addition model predicted higher toxicity than was observed, indicating slight antagonism for the binary mixture. When the pyrethroid synergist piperonyl butoxide (PBO) was added, the model predictions were not significantly different from the observed effects. Brander et al. (2009) offered several explanations for the observed antagonism between the two pyrethroids. Permethrin is a type I pyrethroid, and cyfluthrin is a type II pyrethroid, and type II pyrethroids may be able to outcompete type I pyrethroids for binding sites, which is known as competitive agonism; or binding sites may be saturated, so that complete additivity is not observed. They also note that cyfluthrin is metabolized more slowly than permethrin, so cyfluthrin can bind longer. PBO may remove this effect because the rate of metabolism of both pyrethroids is reduced in its presence.

Callinan et al. (2012) tested pyrethroid mixtures with *Hyalella azteca* in aqueous exposures in the following binary combinations: type I-type I (bifenthrin-permethrin), type I-type II (bifenthrin-cyfluthrin, bifenthrin-lambda-cyhalothrin, permethrin-cyfluthrin, and permethrin-lambda-cyhalothrin) and type II-type II (cyfluthrin-lambda-cyhalothrin). These combinations were tested in 4-day exposures, and two of the combinations were also tested in 10-day chronic exposures. Both the concentration addition and the independent action models were fit to the observed toxicity data and the fits were compared with several statistical analyses. One way of comparing the fits indicated that all combinations of pyrethroids were additive following the concentration addition model.

Another way of comparing the results indicated that there was slight antagonism in two of the pyrethroid combinations (bifenthrin-cyfluthrin and permethrin-cyfluthrin), but only in the 4-day tests, not in the 10-day tests.

Trimble et al. (2009) performed sediment toxicity tests with *Hyalella azteca* in three binary combinations: type I-type I (permethrin-bifenthrin), type II-type II (cypermethrin-λ-cyhalothrin), and type I-type II (bifenthrin-cypermethrin) in order to test differences in pyrethroid mixture toxicity based on pyrethroid type. The toxicity of these combinations was predicted with the concentration addition model, with model deviations within a factor of two. Trimble et al. also fit the mixture toxicity results to the independent action model, which does not assume that the pesticides have the same toxicological mode of action, and this model actually fit the observed toxicity data better than the concentration addition model in two of three cases – for the type I-type I combination and the type II-type II combination. The type I-type II combination was better fit by the concentration addition model even though the modes of action are expected to be the least similar in this case. While the best model to fit joint toxicity of pyrethroids varies by study and by pyrethroid combination, Trimble et al. (2009) concluded that the data in this study indicate that pyrethroid mixture toxicity is likely additive and that the deviations from the concentration addition model reasonably encompass expected intra- and interlaboratory variability.

In all of the studies on pyrethroid mixtures, the mixtures were more toxic than a single pyrethroid tested alone. Several tests indicated some antagonism in pyrethroid mixtures, meaning that the combination was less toxic than expected based on the concentration addition model prediction. However, even in the cases of slight antagonism, the mixture toxicity results fit the concentration addition model within a factor of 2 or less.

The six pyrethroids under consideration for this proposed amendment are either Type I or Type II pyrethroids. The Type I and Type II pyrethroids have the same general mechanism of toxic action, and have been shown to exhibit additive toxicity to aquatic invertebrates when they co-occur (Barata et al. 2006; Brander et al. 2009; Trimble et al. 2009). Studies of mixtures of compounds acting through the same mechanism suggest there is no concentration below which a compound will no longer contribute to the overall toxicity of the mixture (Deneer et al. 1988). Therefore, the total potential toxicity of co-occurring pyrethroids needs to be assessed, even when the individual concentrations would otherwise be below thresholds of concern.

The Basin Plan (p. IV-18.00) provides an additivity formula for toxic substances that applies to pyrethroids because it has been determined that they exhibit additive toxicity. The additivity formula in the Basin Plan is as follows:

Equation 2

$$\sum_{i=1}^{n} \frac{[Concentration\ of\ Toxic\ Substance]_i}{[Toxicologic\ Limit\ for\ Substance\ in\ Water]_i} < 1.0$$

In this equation, the toxicologic limit would be equal to a water quality objective. Additive toxicity of pyrethroids can be addressed by using the above additivity formula when evaluating compliance with the water quality objectives. Addressing additive toxicity will ensure that the cumulative toxic potential of these pesticides is addressed.

Combinations of pyrethroids and other chemicals may also have additive, synergistic, or antagonistic effects on toxicity to aquatic organisms. Interactions between pyrethroids and various pesticides and other chemicals were reviewed by Fojut et al. (2012), and the authors concluded that there is currently not sufficient data to quantify any of these interactions. Thus quantitative limits to account for these interactions are not recommended for inclusion in the Basin Plan at this time.

5.3 **Bioavailability**

Pyrethroid pesticides are hydrophobic organic chemicals, meaning that they have a higher tendency to bind to solids or dissolved organic matter (DOM) than to be dissolved in water. Although pyrethroids are primarily bound to solids and DOM in aquatic environments, aquatic organisms are very sensitive to pyrethroids and toxicity does occur. Pyrethroids have been identified as the cause of toxicity in surface waters and sediment in the Central Valley (Phillips et al. 2007, 2014a; Weston et al. 2009; Weston and Lydy 2010). The fraction of a chemical that an organism is exposed to via intake of the chemical in water, ingestion of the chemical bound to food sources, or direct uptake through membranes is referred to as the bioavailable fraction of the chemical (You et al. 2011). In typical aquatic environments, some fraction of pyrethroid pesticides is bioavailable to the organism, and the remaining fraction is bound to solids and the organism does not interact with and is not exposed to the bound fraction. It should be noted that although the bound fraction is not immediately bioavailable, it may later be released from the bound state and become bioavailable to aquatic organisms. This concept is referred to as bioaccessibility, and may indicate that benthic organisms are at greater risk of longer exposures to pyrethroids because pyrethroids may continue to be released from sediments for long periods (You et al. 2011).

Many researchers have investigated the bioavailability of pyrethroid pesticides and what factors influence bioavailability. These studies have demonstrated that uptake and toxicity of pyrethroids are reduced when sediment, DOM or other natural sorbents are present (Day 1991, DeLorenzo et al. 2006, Lajmanovich et al. 2003, Muir et al. 1985, 1994, Smith and Lizotte 2007, Xu et al. 2007, Yang et al. 2006a, b, c, 2007). In aquatic environments, the amount of suspended solids and other factors that may affect bioavailability may vary greatly by season or when storm or irrigation events occur, and the bioavailability of pyrethroids will also vary with those changes.

The bioavailable fraction of a chemical is the true amount that an organism is exposed to, and for that reason, it would be ideal to use the bioavailable concentration to determine attainment with the pyrethroid water quality objectives. The only way to truly measure the bioavailable concentration of a chemical is to measure the amount taken up by an organism in its tissue (tissue residue analysis), which is not practical because water quality objectives based on tissue residue are not available, and it would require the collection of aquatic organisms to determine attainment of water quality objectives. However, there are several ways to estimate the bioavailable fraction in water and sediment samples. Typical analytical chemistry techniques do not distinguish between the bioavailable fraction and the total pyrethroid concentration occurring in either a water or sediment sample.

Many researchers have demonstrated that the freely dissolved concentration of pyrethroids correlates well with bioavailability to aquatic organisms (Bondarenko et al. 2007, Bondarenko and Gan 2009, Hunter et al. 2008, Xu et al. 2007, Yang et al. 2006a, 2006b, 2007). The freely dissolved concentration of a chemical is that which is not bound to DOC, nor bound to suspended particles, but is truly dissolved in the aqueous phase. The bioavailable concentration is not equivalent to the freely dissolved concentration, because the freely dissolved concentration neglects exposure via ingestion of chemicals bound to food sources, or absorption directly through exterior membranes. However, many studies have demonstrated that the freely dissolved concentration is highly correlated with the bioavailable fraction and is a good predictor of bioavailability.

The most conservative approach for sample analysis would be to use the whole water concentration to determine attainment with the proposed pyrethroids water quality objectives. This would provide a practical and straightforward approach to sample analysis and determining attainment with water quality objectives. Using the whole water concentration may also lead to some water samples being determined to exceed the proposed pyrethroids water quality objectives, when in fact the bioavailable concentration may be well below levels known to cause harm to aquatic organisms.

Accounting for bioavailability of pyrethroids in environmental samples should result in a more accurate predication of potential toxicity to aquatic organisms in aquatic ecosystems. There is ample research that demonstrates using the freely dissolved concentration of pyrethroids provides a good prediction of the bioavailable concentration for aquatic organisms (Day 1991, DeLorenzo et al. 2006, Lajmanovich et al. 2003, Muir et al. 1985, 1994, Smith and Lizotte 2007, Xu et al. 2007, Yang et al. 2006a, b, c, 2007).

Accounting for bioavailability by estimating or measuring the freely dissolved concentrations of pyrethroids is a reasonable approach to protect aquatic life, while accounting for environmental characteristics and reducing the likelihood that samples that would not cause harm to aquatic organisms are not determined to exceed water quality objectives. Approaches for estimating or measuring the freely dissolved concentration are discussed further in the following two sections.

5.3.1 **Measuring freely dissolved concentrations**

The most widely used technique for measuring the freely dissolved concentration is solid-phase microextraction (SPME). This technique involves using a polymer fiber to extract a negligible amount of chemical from the water so that equilibrium is not disturbed in the sample. SPME has been demonstrated to provide good results for freely dissolved concentrations (Bondarenko et al. 2007, Bondarenko and Gan 2009, Hunter et al. 2008, Xu et al. 2007, Yang et al. 2006a, 2006b, 2007). SPME methods have not yet been adopted widely by commercial laboratories and standard methods are not available from U.S. EPA, ASTM or other standardization organizations. The SPME technique could provide more accurate measurements of freely dissolved concentrations compared to estimating the concentration with partitioning coefficients, particularly if site-specific partition coefficients are not used.

Researchers have also filtered water samples prior to chemical analysis to remove suspended solids and/or dissolved organic matter to measure dissolved pyrethroids. Typical syringe filters are not recommended for use when analyzing for pyrethroids because studies have demonstrated that a fraction of the dissolved compounds can adsorb to the filters instead of passing through (Gomez-Gutierrez et al. 2007, House and Ou 1992). These losses to the filter may be important when measuring low environmental concentrations of pyrethroids. However, the U.S. Geological Survey (USGS) has developed a filtration sample handling method specifically for pyrethroids (Hladik et al. 2009). This method involves filtering water through a diaphragm pump, with equipment made from specified materials and flow rates, and for the least losses samples should be filtered in the field. Approximately 3-5% of pyrethroids were lost to surface association in the filtration apparatus, which is considered minimal and acceptable by USGS. The USGS filtration method only removes suspended solids, it does not filter DOC, so the resulting pyrethroid concentration is the sum of the freely dissolved concentration and the concentration bound to DOC. Using this method, the freely dissolved concentration could be calculated if the DOC concentration is measured.

5.3.2 **Estimating freely dissolved concentrations**

The freely dissolved concentration can also be estimated, rather than directly measured, by calculating the amount of binding to suspended solids and DOM. The amount of binding to these phases is typically normalized to the organic carbon content of the materials, because it is presumed that pyrethroid pesticides, like other hydrophobic organic chemicals, primarily bind to the organic carbon (OC) found in solids and DOM. The following equation can be used to estimate the freely dissolved concentration of pyrethroids:

Equation 3

$$C_{dissolved} = \frac{C_{total}}{1+((K_{OC}[POC])+(K_{DOC}[DOC])}$$

where: $C_{dissolved}$ = concentration of chemical in dissolved phase (μg/L);
C_{total} = total concentration of chemical in water (μg/L);
K_{OC} = organic carbon-water partition coefficient (L/kg);
[POC] = concentration of particulate organic carbon (kg/L);
K_{DOC} = organic carbon-water partition coefficient (L/kg) for DOC;
[*DOC*] = concentration of dissolved organic carbon in water (kg/L).

To calculate the freely dissolved concentration with this equation, water samples must be analyzed for the total concentration of each pyrethroid pesticide (C_{total}), the concentration of total organic carbon ([TOC]), and the concentration of dissolved organic carbon ([DOC]). The concentration of particulate organic carbon ([POC]) can then be calculated as: [POC] = [TOC]-[DOC]. Site-specific partition coefficients are recommended for these calculations because organic carbon occurring in the environment can vary widely in their binding properties depending on the physical-chemical properties of the organic matter, which primarily develop based on the source and aging of the material. Site-specific partition coefficients may also vary with season and timing of sample collection because aquatic ecosystems are not static and new sources of material may be introduced due to changes in the surrounding environment. The accuracy of the estimation of the freely dissolved concentration will be improved if site-specific partition coefficients are used, but if site-specific partition coefficients are not available, partition coefficients available in the literature could also be used for this calculation.

Estimating the freely dissolved concentration via partition coefficients may over- or underestimate bioavailability, but one study demonstrated that using site-specific partition coefficients were comparable to direct measurement via SPME. Yang et al. (2006a) measured partition coefficients for four suspended sediments and then used those values to predict LC_{50}'s for *Ceriodaphnia dubia* at various levels of suspended solids for four pyrethroids. They compared these estimated LC_{50}'s to the LC_{50}'s measured by SPME and found that 95% of estimated LC_{50}'s fall within a factor of two of the LC_{50} measured by SPME, indicating that direct measurement by SPME and estimation via partition coefficients are comparable. It is unlikely that site-specific partition coefficients will be available for most monitoring sites because determining these values is not a standard procedure performed by commercial laboratories. Partition coefficients have primarily been reported by academic research laboratories and pesticide registrants.

Because site-specific partition coefficients will likely not be available, default partition coefficients are proposed in order to use Equation 3 to estimate the freely dissolved concentration of a sample. A literature review of existing partition coefficients was conducted and data acceptability criteria were:

- Study followed a standard batch equilibrium experimental design
- The freely dissolved aqueous concentrations were measured using SPME
- Natural sediments were used (not formulated)
- Low solids-to-solution ratios (≤ 2:100)

Three studies were identified that met these criteria and the partition coefficients from these studies are presented in Table 5-1 and Table 5-2. Some data processing was completed to result in the partition coefficients reported in Table 5-1 and Table 5-2. The K_{OC} and K_{DOC} data for permethrin were reported separately for the two diastereomers of permethrin (cis-permethrin and trans-permethrin) by Cui and Gan (2013). Because most formulations of permethrin are approximately 50% cis-permethrin and 50% trans-permethrin, the mean of the values for the two diastereomers was used as the permethrin K_{OC} and K_{DOC} for those data. K_{DOC} values were not explicitly reported by Chickering (2014), but the data necessary to calculate K_{DOC} values were reported. The total aqueous pyrethroid concentration, the freely dissolved aqueous pyrethroid concentration, and the concentration of DOC were used to calculate K_{DOC} using the following equation (Bondarenko and Gan 2009):

Equation 4

$$K_{DOC} = \frac{(C_{total} - C_{dissolved})/[DOC]}{C_{dissolved}}$$

where: K_{DOC} = organic carbon-water partition coefficient (L/kg) for DOC;
C_{total} = total concentration of chemical in water (μg/L);
$C_{dissolved}$ = concentration of chemical in dissolved phase (μg/L);
$[DOC]$ = concentration of dissolved organic carbon in water (kg/L).

Table 5-1 Organic carbon-water partition coefficients (K_{OC}) for pyrethroids.

%OC	Bif (L/kg)	Cyf (L/kg)	Cyp (L/kg)	Esf (L/kg)	L-cy (L/kg)	Per (L/kg)	Reference
6.9	4,049,394	3,983,720	3,105,712	6,365,689	2,077,949	6,329,845	Chickering 2014
6.9	3,682,730	3,449,806	3,484,084	7,851,870	2,160,946	3,719,214	Chickering 2014
6.9	4,952,213	4,176,779	2,726,695	7,442,352	1,929,773	8,174,471	Chickering 2014
5.1	1,330,000	3,330,000	--	14,200,000	2,300,000	4,700,000	Cui & Gan 2013
2.6	1,200,000	2,430,000	--	5,240,000	2,140,000	2,545,000	Cui & Gan 2013
4.9	990,000	3,260,000	--	5,300,000	1,860,000	2,955,000	Cui & Gan 2013
11.3	98,000	560,000	--	570,000	370,000	1,235,000	Cui & Gan 2013
0.5	5,470,000	6,450,000	--	20,900,000	12,130,000	6,075,000	Cui & Gan 2013
0.5	1,720,000	--	1,920,000	3,240,000	--	4,540,000	Yang et al. 2006b
2.45	628,571	--	1,122,449	910,204	--	697,959	Yang et al. 2006b
0.07	11,571,429	--	21,857,143	14,714,286	--	8,714,286	Yang et al. 2006b
1.36	1,794,118	--	2,132,353	1,860,294	--	1,301,471	Yang et al. 2006b

Table 5-2 Dissolved organic carbon-water partition coefficients (K_{DOC}) for pyrethroids.

%OC	Bif (L/kg)	Cyf (L/kg)	Cyp (L/kg)	Esf (L/kg)	L-cy (L/kg)	Per (L/kg)	Reference
5.1	600,000	630,000	--	2,140,000	1,320,000	122,520,000	Cui & Gan 2013
2.6	2,690,000	3,890,000	--	13,300,000	6,430,000	1,750,000	Cui & Gan 2013
4.9	4,410,000	12,890,000	--	19,260,000	6,550,000	17,855,000	Cui & Gan 2013
11.3	7,150,000	20,930,000	--	30,020,000	7,600,000	17,460,000	Cui & Gan 2013
0.5	43,440,000	26,660,000	--	301,540,000	59,180,000	1,215,000	Cui & Gan 2013
6.9	1,203,323	4,043,318	1,152,816	--	754,307	936,577	Chickering 2014

Two alternatives were evaluated for the default partition coefficients (Table 5-3 and Table 5-4): 1) the median (50th percentile) and 2) the 20th percentile of available values that meet the data acceptability criteria. The median, or 50th percentile of a data set, separates the lower half of a data set from the higher half and is less likely to be affected by a single large observation than the mean, thus it is considered a robust measure of the central tendency of the data set. The 20th percentile would be more conservative than the median because lower partition coefficients would result in higher freely dissolved concentrations.

The sorptive properties of sediments and DOC can vary widely, and the goal is to result in the most accurate prediction of the freely dissolved concentration. The median partition coefficients would be more representative of the variability among sediments and DOC compared to the 20th percentile. Use of the 50th percentile would have a similar likelihood of over- or underestimating the freely dissolved concentration, whereas use of the 20th percentile would have a higher likelihood of overestimating the freely dissolved concentration. However, the 20th percentile would lead to greater certainty that when a sample is determined to be attaining the pyrethroids water quality objectives it is not toxic to aquatic organisms.

Partition coefficients are frequently log-transformed for comparison and categorization among chemicals. The log-transformed partition coefficients for the 50th and 20th percentiles, are different by less than 0.5 log units in all cases (Table 5-3 and Table 5-4), which is a relatively small difference when compared to other published values for these compounds.

Table 5-3 Partition coefficient alternatives for K_{OC}s for pyrethroids (L/kg)

	50th percentile		**20th percentile**	
Pyrethroid	**K_{OC}**	**log K_{OC}**	**K_{OC}**	**log K_{OC}**
Bifenthrin	1,757,059	6.24	1,032,000	6.01
Cyfluthrin	3,389,903	6.53	2,762,000	6.44
Cypermethrin	2,726,695	6.44	1,962,471	6.29
Esfenvalerate	5,832,845	6.77	2,136,235	6.33
Lambda-cyhalothrin	2,108,975	6.32	1,887,909	6.28
Permethrin	4,129,607	6.62	1,550,176	6.19

Data sources given in Table 5-1.

Table 5-4 Partition coefficient alternatives for K_{DOC}s for pyrethroids (L/kg)

	50th percentile		**20th percentile**	
Pyrethroid	**K_{DOC}**	**log K_{DOC}**	**K_{DOC}**	**log K_{DOC}**
Bifenthrin	3,550,000	6.08	1,203,323	6.55
Cyfluthrin	8,466,659	6.59	3,890,000	6.93
Cypermethrin	1,152,816	6.06	1,152,816	6.06
Esfenvalerate	19,260,000	7.04	11,068,000	7.28
Lambda-cyhalothrin	6,490,000	6.12	1,320,000	6.81
Permethrin	9,605,000	6.08	1,215,000	6.98

Data sources given in Table 5-2.

Because the goal is to result in the most accurate prediction of the freely dissolved concentration, and there is a relatively small difference between the 50th and 20th

percentile partition coefficients, the staff recommendation is to use the 50th percentile of available values for the default partition coefficients. These partition coefficients could be used in Equation 3 to estimate the freely dissolved concentrations of pyrethroids for comparison to numeric water quality objectives. When the Basin Plan amendment is reviewed in the future, the use of the default partition coefficients based on the 50th percentile should be evaluated. If these default partition coefficients are found to be poor predictors of the freely dissolved concentrations and/or toxicity, then the 20th percentile or other alternatives should be assessed at that time.

It should be noted that the recommended default partition coefficients (Table 5-3 and Table 5-4) are appropriate to use for ambient water samples, and they may not be representative of unique matrices, such as municipal or domestic wastewater treatment plant effluents, or of sediment exposures. Partition coefficients for wastewater effluents are needed to assess the effects of pyrethroids in effluents on ambient waters. One study has determined partition coefficients for four pyrethroids using wastewater effluents and these values can be used for estimating the freely dissolved pyrethroid concentration in effluents. Parry and Young (2013) determined both K_{OC} and K_{DOC} for bifenthrin, lambda-cyhalothrin, cypermethrin, and permethrin based on six samples from the Sacramento Regional Wastewater Treatment Plant. As recommended above, the 50th percentile of K_{OC} values is used as the default K_{OC} for effluents for each pyrethroid, whereas a single K_{DOC} value was reported for each chemical (Parry and Young 2013). Because partition coefficients for wastewater effluents are not available for cyfluthrin and esfenvalerate, the default partition coefficients for ambient waters may be used in cases when these pyrethroids are detected wastewater effluents. However, if partition coefficients specific to municipal and domestic wastewater effluents become available for these compounds in the future, it is recommended that those values are used for assessing pyrethroids in effluents. Recommended partition coefficients for both ambient waters and wastewater effluents are summarized in Table 5-5.

Table 5-5 Recommended default partition coefficients for pyrethroids (L/kg)

	Ambient Waters		**Wastewater Effluents**[a]	
Pyrethroid	**K_{OC}**	**K_{DOC}**	**K_{OC}**	**K_{DOC}**
Bifenthrin	1,757,059	3,550,000	15,848,932	800,000
Cyfluthrin	3,389,903	8,466,659	--	--
Cypermethrin	2,726,695	1,152,816	6,309,573	200,000
Esfenvalerate	5,832,845	19,260,000	--	--
Lambda-cyhalothrin	2,108,975	6,490,000	7,126,428	200,000
Permethrin	4,129,607	9,605,000	10,000,000	200,000

[a]All data from Parry and Young (2013)

5.4 **Pyrethroid-resistant Aquatic Organisms**

The aquatic invertebrate *Hyalella azteca* is known to be particularly sensitive to pyrethroids. Among species tested in the laboratory, *Hyalella azteca* is the most sensitive of all aquatic organisms to all pyrethroids tested. *Hyalella azteca* are also used in ambient toxicity testing and are known to be a sensitive indicator of pyrethroids in surface waters and sediments. While *Hyalella azteca* is typically referred to as a single species, it is actually known to be a species complex, meaning that different populations may vary in size, life-history characteristics, and genetic diversity (Major et al. 2013). Two recent studies have demonstrated that field populations of *Hyalella azteca* have variable sensitivities to pyrethroids and these results are described below (Weston et al. 2013b, Clark et al. 2015). Some field populations tested had equivalent sensitivities to pyrethroids as laboratory-reared organisms, whereas other field populations were up to 550 times more tolerant of pyrethroids compared to laboratory-reared populations (Weston et al. 2013b).

Weston et al. (2013b) collected *Hyalella azteca* from seven sites in California with varying land use, including undeveloped grasslands, commercial and residential sites, and agricultural sites. The researchers performed genetic analysis on the field populations and determined that they belonged to three different groups (called clades). They also analyzed three populations of laboratory-reared organisms and found all of them belonged to a fourth clade. The researchers noted that sensitivity to pyrethroids varied by clade and was also correlated to land use. The populations from sites with few pyrethroid inputs and little or no detected pyrethroids in stream sediments were equally sensitive to pyrethroids as laboratory-reared cultures. In contrast, the populations from sites with higher pyrethroid sediment concentrations demonstrated the highest degree of resistance to pyrethroids; they were up to 550 times more tolerant to pyrethroids compared to laboratory-reared populations.

The researchers did genetic analysis on the populations to investigate mechanisms of resistance and found multiple genetic mutations in the resistant field populations. These same mutations have also been identified in pesticide-resistant agricultural pests, indicating that the mutated *Hyalella azteca* were likely exposed to pyrethroids or other similarly acting chemicals over multiple generations. The individuals with the mutations that allow these organisms to tolerate high concentrations of pyrethroids survived and passed on the mutations to the following generations, while those without the mutations did not survive to pass on their genes, potentially reducing the overall genetic and biological diversity of the populations. Weston et al. state that the consequences of these evolutionary changes in *Hyalella azteca* populations are unknown for the species and for aquatic ecosystems, but reduced genetic diversity can result in populations that do not have genetic variations to tolerate other stressors. The authors also highlight the importance of knowing the genetic group and sensitivity of the laboratory cultures used in ambient toxicity testing so that results from different labs are truly comparable.

Clark et al. (2015) identified several field populations of *Hyalella azteca* that were significantly more tolerant of the pyrethroids bifenthrin and cypermethrin compared to laboratory-reared cultures. Field populations in drainages with agricultural and urban influences were more likely to be resistant to pyrethroids compared to those from undeveloped drainages. Organisms from urban drainages were consistently the least sensitive to pyrethroids. This may be a reflection of exposure to pyrethroids because urban drainages are known to have consistently high loads of pyrethroids. Field populations from undeveloped areas had approximately equal sensitivity to pyrethroids as laboratory cultures.

Seasonal variations were also identified at sites where organisms were collected and tested at different times of year. In urban drainages, organisms collected in October were more sensitive to pyrethroids than those collected the following May. Organisms are exposed to many contaminants in winter and spring storm water runoff and exposure to contaminants is known to induce detoxification enzymes. Increased activity of detoxification enzymes would allow an organism to metabolize contaminants more efficiently, which would lead to greater tolerance of contaminants among surviving organisms. *Hyalella azteca* collected from agricultural drainages were more sensitive in January than those collected in June and May. Again, it is possible that organisms are exposed to a flush of contaminants in winter and spring due to storm water runoff, and by May and June they have decreased sensitivity to pyrethroids due to induction of detoxification enzymes. Under this scenario, organisms would be most sensitive to contaminants when first flush storm events occur.

Clark et al. also looked at changes in sensitivity over successive generations of field-collected *H. azteca.* The field-collected organisms were cultured in the laboratory in pyrethroid-free conditions and subsequent generations were tested for pyrethroid sensitivity. The F3 generations of two of the most resistant populations were tested and the cypermethrin LC_{50} for each population decreased approximately an order of magnitude compared to the field-collected F0 generations. However, the F3 generations from these populations were still more sensitive than populations from undeveloped areas or laboratory cultures by approximately a factor of 5-10. This indicates that it is unlikely that a permanent genetic adaptation has occurred, although genetic analysis was not performed so that cannot be confirmed for these populations. The authors point out that there are likely multiple factors that could lead field populations to be resistant to pyrethroids compared to laboratory cultures, including the ability to acclimate to the presence of contaminants by induction of detoxification enzymes, variations in pyrethroids tolerance among *H. azteca* subpopulations, and genetic adaptations.

Based on the two available studies that have identified pyrethroid-resistant field populations in the Project Area, it appears that multiple factors likely account for the development of resistance to pyrethroids in these field populations (Weston et al. 2013b, Clark et al. 2015). Genetic mutations are passed on from one generation to the next and are an indication that the populations have been exposed to high levels of chemicals for long periods of time, and are a sign of population-level effects of contaminants (Weston et al. 2013b). The populations with genetic mutations all occurred in areas expected to have a history of high contaminant loads, such as urban storm drains and agricultural drainages. Metabolic acclimation may only occur in the presence of pyrethroids or other contaminants and are not permanent traits passed on to subsequent generations (Clark et al. 2015).

Metabolic alteration in the presence of contaminants allows the organism to detoxify and excrete the contaminant, which is a normal process, but this may be a significant use of energy over the organism's lifetime. Because it is clear that some populations of *Hyalella azteca* already have genetic mutations to tolerate high loads of pyrethroids and other similar chemicals, this population-level effect should not be overlooked. In order to be protective of all populations of *Hyalella azteca* and other aquatic organisms and to reduce the likelihood of further pressure toward genetic mutations solely based on high levels of contaminants, the water quality objectives should protect those species and populations that have not yet developed resistance to pyrethroids. It is appropriate that none of the proposed water quality objectives include consideration of resistant populations or use toxicity data from resistant populations.

5.5 **Aqueous Concentrations – Water Quality Objective Alternatives**

Water quality objective alternatives for aqueous concentrations of pyrethroids are evaluated in this section. Available water quality criteria (WQC) and guidelines for pyrethroids are presented in Table 5-7 for the protection of aquatic life and human health (drinking water and recreational purposes). Based on the available values, the aquatic life freshwater habitat beneficial uses (WARM/COLD) are far more sensitive to pyrethroids than the drinking water and recreational uses. The available criteria and guidelines to protect the aquatic life beneficial use are further evaluated in this section. The values for drinking water and recreational uses are not further evaluated because they are orders of magnitude larger than the aquatic life values and surface water monitoring data indicates that ambient concentrations are far below these values.

There are thirteen alternatives considered for establishing water quality objectives for pyrethroids:

1. No change in water quality objectives (continue to interpret narrative objectives);
2. No pyrethroids in the water column;
3. California Department of Fish and Wildlife (CDFW) interim water quality criteria;

4. 2010/11 University of California Davis method water quality criteria;
5. 2015 water quality criteria derived via University of California Davis method;
6. Water quality criteria based on 5th percentile derived via University of California Davis method;
7. 2015 water quality criteria derived via USEPA method;
8. Pyrethroid Working Group (PWG) combined species sensitivity distribution for acute toxicity of pyrethroids to arthropods;
9. Australia/New Zealand trigger;
10. Canadian interim freshwater quality guidelines;
11. Dutch maximum permissible concentrations;
12. USEPA Office of Pesticide Programs aquatic life benchmarks;
13. One-tenth of the lowest LC_{50} from 2015 data sets (Basin Plan guidance).

First, these alternatives were evaluated based on the following factors to determine whether they should be further considered as potential water quality objectives:

- Data sources and calculation method were clearly identified so that sources can be checked for quality and errors
- Availability of both acute and chronic criteria to ensure protection from both short-term and longer exposures
- Availability for the six pyrethroids of interest
- Protection of known sensitive species (e.g., data in Table 5-6)
- Consistency with other regulations and criteria derivation methodologies.

Table 5-6 Toxicity values for *Hyalella azteca* in aqueous and sediment exposures

	Aqueous LC_{50} (ng/L)	Sediment LC_{50} (μg/g OC)
Bifenthrin	0.50[a]	0.43 (geomean, n=4)[g,h]
Cyfluthrin	0.55[b]	1.08 (geomean, n=2)[g]
Cypermethrin	0.56[c]	0.34 (geomean, n=3)[i]
Esfenvalerate	0.85[d]	1.53 (geomean, n=3)[g]
λ-cyhalothrin	0.3[e]	0.45 (mean, n=2)[g]
Permethrin	7.0[f]	8.68 (geomean, n=3)[g]

[a]Bradley 2013a, [b]Bradley 2013b, [c]Bradley 2013c, [d]Bradley 2013d, [e]Bradley 2013e, [f]Bradley 2013f, [g]Amweg et al. 2005, [h]Amweg and Weston 2007, [i]Maund et al. 2002.

Alternatives that were further considered based on the above factors were then evaluated based on Porter-Cologne considerations and other applicable laws and policies. Section 13241 of Porter-Cologne specifies the following considerations in establishing water quality objectives: 1) past, present, and probable future beneficial uses of water, 2) environmental characteristics of hydrographic unit, including quality of water available to it, 3) water quality conditions reasonably achievable through coordinated control of all factors that affect water quality in the area, 4) economic considerations, 5) the need for developing housing within the region, and 6) the need to develop and use recycled water. The recommendations regarding additivity and bioavailability of pyrethroids (sections 5.2 and 5.3) were considered when evaluating based on the Porter-Cologne considerations.

Table 5-7 Available water quality criteria and guidelines for pyrethroids.

	Bifenthrin (ng/L)	Cyfluthrin (ng/L)	Cypermethrin (ng/L)	Esfenvalerate (ng/L)	Lambda-cyhalothrin (ng/L)	Permethrin (ng/L)
Aquatic life criteria and guidelines for freshwater surface waters						
CDFW interim acute[a]	NA	NA	2	NA	NA	30
2010/11 UCD acute[b]	4	0.3	1	NA	1	10
2010/11 UCD chronic[b]	0.6	0.05	0.2	NA	0.5	2
2015 acute via UCD method	0.06[c]	0.07[d]	0.04[e]	0.2[f]	0.03[g]	6[h]
2015 chronic via UCD method	0.01[c]	0.01[d]	0.01[e]	0.03[f]	0.01[g]	1[h]
5th percentile 2015 acute via UCD method	0.8[c]	0.8[d]	1[e]	2[f]	0.7[g]	6[h]
5th percentile 2015 chronic via UCD method	0.1[c]	0.2[d]	0.3[e]	0.3[f]	0.3[g]	1[h]
2015 acute via USEPA method	0.059[c]	NA	0.25[e]	NA	0.21[g]	4[h]
2015 chronic via USEPA method	NA	NA	NA	NA	0.087[g]	NA
PWG SSD acute[i]	1.3	1.5	3.0	2.3	0.8	19
Australia/New Zealand trigger[j]	NA	NA	NA	1	NA	NA
Canadian interim guideline (chronic)[k]	NA	NA	NA	NA	NA	4
Dutch maximum permissible conc. (chronic)[l]	1.1	NA	0.09	NA	NA	0.2
USEPA OPP aquatic life benchmark – invertebrates[m] (acute; chronic)	800; 1.3	12.5; 7	210; 69	25; 17	3.5; 2	10; 1.4
USEPA OPP aquatic life benchmark – fish[m] (acute; chronic)	75; 40	34; 10	195; 140	35; 35	105; 31	395; 51.5
1/10th lowest LC_{50}	0.05[n]	0.055[o]	0.056[p]	0.085[q]	0.03[r]	0.7[s]
Human health guidelines for drinking water						
USEPA human health benchmark – acute (1d-children)[t]	3,300,000	200,000	1,000,000	18,000	50,000 (γ-cyh: 25,000)	2,500,000
USEPA human health benchmark – chronic (lifetime)[t]	91,000	168,000	420,000	13,000	7,000	1,750,000
Water quality guidelines for recreational purposes						
Australia/New Zealand maximum concentration[j]	NA	NA	NA	Fenvalerate 40,000	NA	300,000

[a]Siepmann and Holm 2000; [b]Fojut et al. 2012; [c]Fojut 2015a; [d]Fojut 2015b; [e]Fojut 2015c; [f]Fojut 2015d; [g]Fojut 2015e; [h]Fojut 2015f; [i]Giddings et al. 2014; [j]ANZECC/ARMCANZ 2000; [k]CCME 2006; [l]Crommentuijn et al. 2000; [m]USEPA 2012a; [n]Bradley 2013a; [o]Bradley 2013b; [p]Bradley 2013c; [q]Bradley 2013d; [r]Bradley 2013e; [s]Bradley 2013f; [t]USEPA 2012b, 2013.

5.5.1 No Change in Water Quality Objectives

The Basin Plan currently contains narrative water quality objectives regarding pesticides and toxicity. The Central Valley Water Board uses available guidelines and criteria to interpret existing narrative water quality objectives. The Central Valley Water Board has not established any criteria to interpret compliance with its narrative toxicity and pesticide water quality objectives specifically for pyrethroids.

The Basin Plan states that the Central Valley Water Board will use the best available technical information to evaluate compliance with narrative objectives pertaining to pesticides, and will consider one-tenth of the 96-hour LC_{50} of the most sensitive organism as the daily maximum for protection of aquatic life. Other available information, such as the Lowest Observed Effect Concentrations and No Observed Effect Levels, are to be evaluated to determine whether lower concentrations are required to interpret narrative objectives. These types of information are recommended for consideration because water quality criteria and other guidance are not typically available for many pesticides.

The 96-hour LC_{50}s of the most sensitive organism for each of the six pyrethroids and 1/10 of those LC_{50} values are summarized in Table 5-8. These values would not likely be chosen to interpret the narrative water quality objectives regarding pesticides and toxicity for pyrethroids because other water quality criteria and guidance is available for pyrethroids.

On the most recent 303(d) list for the Central Valley Region, one-tenth of the lowest LC_{50} was used for evaluation guidelines for bifenthrin and cis-permethrin, using older data than shown in Table 5-8 (SWRCB 2010). The evaluation guidelines used for those listings were 0.00093 μg/L for bifenthrin and 0.033 μg/L for cis-permethrin. However, water quality criteria recently became available for five pyrethroids (Fojut et al. 2012), and these criteria have been used by Regional Boards to interpret narrative objectives for pyrethroids more recently (CRRWQCB 2014). The “no change” alternative will be further considered for pyrethroids, since it would apply if numeric water quality objectives were not established.

Table 5-8 One-tenth of the lowest LC_{50} for six pyrethroids.

Pesticide	*Hyalella azteca* 96-hour LC_{50} (ng/L)	1/10 96-hour LC_{50} (ng/L)
Bifenthrin	0.5[a]	0.05
Cyfluthrin	0.55[b]	0.055
Cypermethrin	0.56[c]	0.056
Esfenvalerate	0.85[d]	0.085
Lambda-cyhalothrin	0.3[e]	0.03
Permethrin	7[f]	0.7

[a]Bradley 2013a, [b]Bradley 2013b, [c]Bradley 2013c, [d]Bradley 2013d, [e]Bradley 2013e, [f]Bradley 2013f.

5.5.2 No Pyrethroids in the Water Column

The Central Valley Water Board could adopt water quality objectives that would maintain “natural” water quality conditions. Water quality objectives based on these conditions would mean that detectable levels of pyrethroids in the water column would not be allowed. State and federal antidegradation policies allow for the presence of pyrethroids if that presence is consistent with maximum benefit to the people of the state, does not unreasonably affect present and anticipated beneficial uses, and does not result in water quality less than that prescribed in existing policies (State Water Board Resolution 68-16 and 40 CFR 131.12).

The Central Valley Water Board could make a determination that allowing the presence of any pyrethroids in surface waters is not to the maximum benefit of the people of the state, which would serve as the basis for a no pyrethroids objective. Alternatively, the Central Valley Water Board could determine that allowing the presence of some pyrethroids is consistent with the maximum benefit to the people of the state, but that the concentration consistent with the maximum benefit is less than the highest concentration that would be protective of beneficial uses.

This alternative will be further considered because antidegradation policies allow the Central Valley Water Board to make a determination that the presence of any pyrethroids in any Sacramento or San Joaquin River basin water body is not to the maximum benefit of the people of the state.

5.5.3 CDFW Interim Criteria

The California Department of Fish and Wildlife (formerly the California Department of Fish and Game) completed a hazard assessment of the pyrethroids bifenthrin, cypermethrin, esfenvalerate, and permethrin (Siepmann and Holm 2000). This assessment used the USEPA methodology for deriving numeric water quality criteria (USEPA 1985). The USEPA methodology provides guidelines for reviewing available toxicity data for a water quality constituent and to derive two values – the criterion maximum concentration (CMC), an acute criterion, and the criterion continuous concentration (CCC), a chronic criterion. The method aims to protect aquatic organisms and their uses by restricting concentrations to levels at or below the criteria.

The USEPA method uses toxicity test data from a variety of taxonomic and functional groups, and the available species act as surrogates for other untested species. There are eight required taxa in this method: 1) the family Salmonidae (class Osteichthyes), 2) a second family in the class Osteichthyes, 3) a third family in the phylum Chordata, 4) a planktonic crustacean, 5) a benthic crustacean, 6) an insect, 7) a family in a phylum other than Arthropoda or Chordata, and 8) a family in any order of insect or any phylum not already represented. Because these data represent a variety of taxa and functions, the resulting criteria should protect the aquatic ecosystem. The criteria are derived by using a species sensitivity distribution (SSD) approach. The criteria are met if the one-hour average concentration of the constituent does not exceed the CMC and the four-day average concentration does not exceed the CCC more than once every three years, on average.

There were insufficient data available for CDFW to calculate any type of criteria for bifenthrin or esfenvalerate. The bifenthrin acute data set contained three of the eight required taxa, while the chronic data set contained only one of the eight taxa requirements. Only four of the eight taxa requirements were met for acute esfenvalerate data and one of eight were available for chronic data.

For cypermethrin, seven of the eight required taxa were available, with the missing taxon being a phylum not already represented. Because this missing taxon was not expected to be particularly sensitive to pyrethroids, CDFW calculated an interim acute criterion, or CMC, of 0.002 μg/L with the incomplete data set. Similarly, an interim freshwater CMC of 0.03 μg/L was calculated for permethrin based on a data set that fulfilled seven of the eight taxa requirements. A final saltwater CMC of 0.001 μg/L was calculated because all eight of the taxa requirements were fulfilled for saltwater species. Chronic criteria were not calculated for cypermethrin and permethrin because there were insufficient data.

In summary, the CDFW hazard assessment concluded that there were insufficient data to derive criteria for bifenthrin and esfenvalerate, according to the data requirements of the USEPA method. Relatively more data were available for cypermethrin and permethrin, but these data sets were still incomplete, thus CDFW derived interim acute criteria for these compounds. Numeric objectives are only available for cypermethrin and permethrin under this alternative. Because this alternative does not provide both acute and chronic values, only has values for two of the six pyrethroids, and they do not appear to be protective of the most sensitive species in current toxicity data sets, these values will not be further considered for use as water quality objectives.

5.5.4 **2010/11 UC Davis Water Quality Criteria**

The Central Valley Water Board contracted with UC Davis to develop a new methodology to establish water quality criteria for the protection of aquatic life based on findings from a review of current methodologies (TenBrook et al. 2009). The methodology developed by UC Davis incorporates procedures that could improve criteria generation. Similarly to the USEPA method, the goal of the UC Davis method is to extrapolate from available pesticide toxicity data for a limited number of species to a concentration that should not produce detrimental physiological effects in aquatic life (TenBrook et al. 2010).

The UC Davis method provides an approach to review available toxicity data for a water quality constituent and to derive two values, an acute criterion and a chronic criterion. The UC Davis methodology has the ability to handle data sets that do not meet the eight taxa requirements of the USEPA method (USEPA 1985). Toxicity data for all of the taxa required by the USEPA methodology are seldom available for pesticides, thus it is often not possible to generate criteria using the USEPA methodology with existing data, as demonstrated by the CDFW hazard assessment. The UC Davis method uses a species sensitivity distribution to derive criteria that is similar to the SSD in the USEPA method. Unlike the eight taxa requirements of the USEPA method, the UC Davis SSD method requires a minimum of five taxa to derive a criterion, which are 1) the family Salmonidae, 2) a warm water fish, 3) a planktonic crustacean, of which one must be in the family Daphniidae in the genus *Ceriodaphnia, Daphnia,* or *Simocephalus,* 4) a benthic crustacean, and 5) an insect (aquatic exposure).

In addition, the UC Davis method can be used to derive acute and chronic criteria when the five SSD taxa requirements are not met. For acute criteria, the method uses an assessment factor with a minimum of one datum from the family Daphniidae in the genus *Ceriodaphnia, Daphnia,* or *Simocephalus*. For acute criterion derivation, the method outlines data requirements if more than one datum is available, but less than the five required species (TenBrook et al. 2010). When fewer than five toxicity values are available to derive a chronic criterion, the UC Davis method uses acute-to-chronic ratios (ACRs) to extrapolate from the acute data to a chronic criterion. An ACR is calculated by dividing an acute LC/EC_{50} value by a chronic value, such as a maximum acceptable toxicant concentration (MATC), from the same or similar tests. ACRs must be available for three species, but when data are not available for three species, a default ACR is used to derive a chronic criterion. A default ACR of 12.4, based on the 80^{th} percentile of ACRs for eight pesticides, was given in the original methodology (TenBrook et al. 2010), although this value has been updated to 11.4 with the addition of more recent criteria data (Fojut et al. 2014).

Criteria developed using the UC Davis method aim to protect all species in the aquatic ecosystem. The criteria are attained if the average concentration from a one-hour period does not exceed the acute criterion and the average concentration from a four-day period does not exceed the chronic criterion more than once every three years, on average.

In addition, the UC Davis method outlines procedures to evaluate derived criteria to ensure that they are set at levels that will protect against adverse effects to 1) sensitive species, 2) species in the ecosystem, and 3) threatened or endangered species (TenBrook et al. 2010). In cases when such data show toxicity can occur at a lower concentration than the acute or chronic criteria derived with the 5^{th} percentile value, the criteria may be adjusted downward to ensure protection. In 2010 and 2011, UC Davis derived water quality criteria for five pyrethroids, which are summarized below from Fojut et al. (2012). All of the UC Davis pyrethroids water quality criteria are intended to be compared to freely dissolved concentrations (vs. whole water) because binding to suspended solids and dissolved organic matter, which are found in ambient waters at varying levels, reduces the bioavailability and toxicity of these compounds. The pyrethroids water quality criteria are also intended to be considered additively because all of the compounds have the same or similar mode of toxic action.

- Bifenthrin (Fojut et al. 2012): The acceptable acute data set contained eight species mean acute values, which were used to calculate an acute freshwater criterion of 4 ng/L using the 5th percentile of a log-logistic SSD. The acceptable chronic data set contained two species mean chronic values, but neither could be paired with appropriate acute data. The chronic criterion was calculated with the default acute-to-chronic ratio of 12.4, which resulted in a chronic freshwater criterion of 0.6 ng/L for bifenthrin.

- Cyfluthrin (Fojut et al. 2012): Eight species mean acute values were available to calculate an acute freshwater criterion of 0.3 ng/L using a log-logistic SSD. There were three species mean chronic values, which were paired with corresponding acute data to calculate a cyfluthrin ACR of 10.27. This ACR was used to calculate a chronic freshwater criterion of 0.05 ng/L. The criteria were calculated using the 1st percentile of the log-logistic distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Cypermethrin (Fojut et al. 2012): The acceptable data set contained 14 species mean acute values, which were used to derive a freshwater acute criterion of 1 ng/L with a Burr Type III SSD. There was only one species mean chronic value available, so default ACRs were included to derive the chronic freshwater criterion of 0.2 ng/L. The criteria were calculated using the 1st percentile of the Burr III distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Lambda-cyhalothrin (Fojut et al. 2012): There were 20 species mean acute values in the acceptable data set, which resulted in an acute freshwater criterion of 1 ng/L using the 5th percentile of a Burr Type III SSD. There were two species mean chronic freshwater values and a saltwater chronic value that were paired with corresponding acute data to calculate a lambda-cyhalothrin ACR of 4.73. This ACR was used to calculate a freshwater chronic criterion of 0.5 ng/L.

- Permethrin (Fojut et al. 2012): There were 19 species mean acute values and an acute freshwater criterion of 10 ng/L was derived using the 5th percentile of a Burr Type III SSD. There were three species mean chronic values in the acceptable data set, but none could be paired with appropriate acute data to calculate ACRs. One saltwater chronic value was paired with corresponding acute data and that ACR was combined with two default ACRs to result in an ACR of 8.96. This ACR was used to calculate a chronic freshwater criterion of 2 ng/L.

USEPA recently promulgated a total maximum daily load (TMDL) for Oxnard Drain 3 in Ventura County, California for bifenthrin using the UC Davis chronic criterion of 0.6 ng/L as the numeric target (USEPA 2011). They chose this value to be protective of aquatic life in both aqueous and sediment matrices. The UC Davis acute and chronic criteria for bifenthrin, cyfluthrin, and lambda-cyhalothrin were also used as numeric targets in the Central Coast Water Quality Control Board's Santa Maria Watershed TMDL for Toxicity and Pesticides (Meertens 2014). The Santa Maria Watershed TMDL also included additive toxicity targets for the identified pyrethroids in sediment.

This alternative does provide acute and chronic values for five of the six pyrethroids of interest and would be consistent with other recent regulations in California; however, these criteria do not appear to be protective of sensitive species based on more recent data, so this alternative will not be further considered.

5.5.5 **2015 water quality criteria derived via University of California Davis method**

Since UC Davis water quality criteria for five pyrethroids were originally derived in 2010 and 2011 (section 5.5.4), additional toxicity data has been generated for these pesticides. In 2015, staff of the Central Valley Regional Board derived updated water quality criteria using the UC Davis methodology, the information gathered in the original criteria reports, as well as recently generated or identified toxicity data.

There were several factors that led staff to conclude that it was important to calculate updated criteria. One factor is that recent toxicity data for the sensitive species *Hyalella azteca* were available from high quality consistent tests that were not included in any of the original criteria reports. Another factor was that a draft water quality criteria for esfenvalerate was derived in 2014 (Trunelle et al. 2014), and had not yet been finalized. In addition, the default acute-to-chronic ratio of the UC Davis method was updated in 2014 to include ACRs for two pyrethroids (cyfluthrin and lambda-cyhalothrin), and thus would be more appropriate and representative of these compounds compared to the original default ACR that did not include data for any pyrethroids. The updated default ACR is 11.4 and is the 80th percentile of ACRs for ten pesticides (Fojut et al. 2014). The original ACR in the UC Davis method was 12.4 (TenBrook et al. 2010).

Central Valley Regional Board staff began with the information gathered in the original UC Davis water quality criteria reports and added recently generated or identified toxicity data to derive water quality criteria for six pyrethroids following the UC Davis method, which are summarized below. As with the 2010/11 UC Davis criteria, the 2015 water quality criteria are intended to be compared to freely dissolved concentrations (vs. whole water) because binding to suspended solids and dissolved organic matter, which are found in ambient waters at varying levels, reduces the bioavailability and toxicity of these compounds. The 2015 pyrethroids water quality criteria are also intended to be considered additively because all of the compounds have the same or similar mode of toxic action.

- Bifenthrin (Fojut 2015a): The acceptable acute data set contained eight species mean acute values, which were used to calculate an acute freshwater criterion of 0.6 ng/L using a log-logistic SSD. Acute values for *Ceriodaphnia dubia* and *Hyalella azteca* were updated in the 2015 acute data set compared to the 2010 data set; all other acute values remained the same. The 2015 acceptable chronic data set contained four species mean chronic values, but none could be paired with appropriate acute data. Chronic values for *Ceriodaphnia dubia* and *Hyalella azteca* were available for the 2015 acute data that were not in the 2010 data set. The 2015 chronic criterion was calculated with the updated default acute-to-chronic ratio of 11.4, which resulted in a chronic freshwater criterion of 0.01 ng/L for bifenthrin. The criteria were calculated using the 1st percentile of the log-logistic distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Cyfluthrin (Fojut 2015b): Eight species mean acute values were available to calculate an acute freshwater criterion of 0.07 ng/L using a log-logistic SSD. The acute value for *Hyalella azteca* was updated in the 2015 acute data set compared to the 2010 data set; all other acute values remained the same. As in the 2010 criteria, there were three species mean chronic values, which were paired with corresponding acute data to calculate a cyfluthrin ACR of 10.27. This ACR was used to calculate a chronic freshwater criterion of 0.01 ng/L. The criteria were calculated using the 1st percentile of the log-logistic distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Cypermethrin (Fojut 2015c): The acceptable acute data set contained 18 species mean acute values, which were used to derive a freshwater acute criterion of 0.04 ng/L with a Burr Type III SSD. Acute values for *Hyalella azteca* and *Oncorhynchus mykiss* were updated and acute values for *Baetis rhodani, Chironomus dilutes, Lepomis macrochirus,* and *Orconectes spp.* were added to the 2015 acute data set compared to the 2010 data set; all other acute values remained the same. Two freshwater species mean chronic value available, but neither could be paired with corresponding acute data to calculate ACRs. *Daphnia magna* was added to the 2015 chronic data set compared to the 2010 data set. However, paired acute and chronic values were available for one saltwater species, and this ACR was combined with two default ACRs resulting in a cypermethrin ACR of 9.2. This ACR was used to calculate a freshwater chronic criterion of 0.01 ng/L. The criteria were calculated using the 1st percentile of the log-logistic distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Esfenvalerate (Fojut 2015d): The acceptable data set contained eight species mean acute values, which were used to derive a freshwater acute criterion of 0.2 ng/L with a log-logistic SSD. There were three species mean chronic values available, and one could be paired with a corresponding acute value to calculate an ACR. This ACR was combined with two default ACRs resulting in a cypermethrin ACR of 12.2. This ACR was used to calculate a freshwater chronic criterion of 0.03 ng/L. The criteria were calculated using the 1st percentile of the log-logistic distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Lambda-cyhalothrin (Fojut 2015e): There were 20 species mean acute values in the acceptable data set, which resulted in an acute freshwater criterion of 0.03 ng/L using a Burr Type III SSD. The only change in the acute data set between the 2010 and 2015 data sets was that the acute value for *Hyalella azteca* was updated. As in the 2010 criteria, there were two species mean chronic freshwater values and a saltwater chronic value that were paired with corresponding acute data to calculate a lambda-cyhalothrin ACR of 4.73. This ACR was used to calculate a freshwater chronic criterion of 0.01 ng/L. The criteria were calculated using the 1st percentile of the log-logistic distribution because the criteria based on the 5th percentile were not protective of the most sensitive species in the data set.

- Permethrin (Fojut 2015f): There were 20 species mean acute values and an acute freshwater criterion of 6 ng/L was derived using the 5th percentile of a Burr Type III SSD. The acute value for *Hyalella azteca* was updated and an acute value for *Hexagenia bilineata* was added to the 2015 acute data set compared to the 2011 data set; all other acute values remained the same. There were three species mean chronic values in the acceptable data set, but none could be paired with appropriate acute data to calculate ACRs. As in the 2011 criteria, one saltwater chronic value was paired with corresponding acute data. The saltwater ACR was combined with two default ACRs to result in an ACR of 8.5. This ACR was used to calculate a chronic freshwater criterion of 1 ng/L.

This alternative will be further considered because acute and chronic criteria are available for all six pyrethroids of interest and the values are protective of sensitive species in current data sets.

5.5.6 Water quality criteria based on 5th percentile derived via University of California Davis method

The UC Davis methodology recommends that criteria should first be calculated with the 5th percentile value of the species sensitivity distribution, but then those criteria should be compared to the most sensitive values in the data set, toxicity values for threatened and endangered species, and data from ecosystem level studies to ensure that sensitive species, including threatened and endangered species, are protected. If the criteria derived with the 5th percentile of the distribution do not appear to be protective of all species in the data set, then the guidance in the UC Davis method is to adjust the criteria downward using the next lowest estimate from the distribution. Five of the six 2015 water quality criteria derived using the UC Davis method were adjusted based on data for sensitive species. In these five criteria, the 1st percentile of the distribution was used to calculate the acute and chronic criteria instead of the 5th percentile of the distribution. In many criteria derivation methodologies from around the world, the 5th percentile is the recommended distributional estimate for criteria derivation, thus the water quality criteria calculated with 5th percentile values using the 2015 data sets are included as an alternative for consideration of water quality objectives.

- Bifenthrin (Fojut 2015a): The acceptable acute data set containing eight species mean acute values was used to calculate an acute freshwater criterion of 0.8 ng/L using the 5th percentile of a log-logistic SSD. The 2015 acceptable chronic data set contained four species mean chronic values, but none could be paired with appropriate acute data. The chronic criterion of 0.1 ng/L was calculated with the updated default acute-to-chronic ratio of 11.4 and the acute 5th percentile value.

- Cyfluthrin (Fojut 2015b): Eight species mean acute values were available to calculate an acute freshwater criterion of 0.8 ng/L using the 5th percentile of a log-logistic SSD. The three species mean chronic values were paired with corresponding acute data to calculate a cyfluthrin ACR of 10.27. The chronic criterion of 0.2 ng/L was calculated with the cyfluthrin ACR and the acute 5th percentile value.

- Cypermethrin (Fojut 2015c): The acceptable acute data set containing 18 species mean acute values was used to calculate a freshwater acute criterion of 1 ng/L with the 5th percentile of a Burr Type III SSD. Two freshwater species mean chronic value available, but neither could be paired with corresponding acute data to calculate ACRs. However, paired acute and chronic values were available for one saltwater species, and this ACR was combined with two default ACRs resulting in a cypermethrin ACR of 9.2. The chronic criterion of 0.3 ng/L was calculated with the cypermethrin ACR and the acute 5th percentile value.

- Esfenvalerate (Fojut 2015d): The acceptable data set containing eight species mean acute values was used to derive a freshwater acute criterion of 2 ng/L with the 5th percentile of a log-logistic SSD. There were three species mean chronic values available, and one could be paired with a corresponding acute value to calculate an ACR. This ACR was combined with two default ACRs resulting in a cypermethrin ACR of 12.2. The chronic criterion of 0.3 ng/L was calculated with the esfenvalerate ACR and the acute 5th percentile value.

- Lambda-cyhalothrin (Fojut 2015e): There were 20 species mean acute values in the acceptable data set, which resulted in an acute freshwater criterion of 0.7 ng/L using the 5th percentile of a Burr Type III SSD. As in the 2010 criteria, there were two species mean chronic freshwater values and a saltwater chronic value that were paired with corresponding acute data to calculate a lambda-cyhalothrin ACR of 4.73. This ACR was used with the acute 5th percentile value to calculate a freshwater chronic criterion of 0.3 ng/L.

- Permethrin (Fojut 2015f): There were 20 species mean acute values and an acute freshwater criterion of 6 ng/L was derived using the 5th percentile of a Burr Type III SSD. There were three species mean chronic values in the acceptable data set, but none could be paired with appropriate acute data to calculate ACRs. As in the 2011 criteria, one saltwater chronic value was paired with corresponding acute data. The saltwater ACR was combined with two default ACRs to result in an ACR of 8.5. This ACR was used with the acute 5th percentile value to calculate a chronic freshwater criterion of 1 ng/L.

This alternative provides acute and chronic criteria for all six pyrethroids of interest, although for five of the pyrethroids, these criteria are not protective of the most sensitive species in current data sets. However, using the 5th percentile would be more consistent with other criteria derivation methodologies, thus this alternative will be further considered.

5.5.7 **2015 water quality criteria derived via USEPA method**

In the UC-Davis criteria reports for pyrethroids, the authors used the data sets gathered according to the UC Davis method to derive criteria according to the USEPA method (Table 5-9). These criteria were not issued or reviewed by the USEPA, but did follow the USEPA 1985 Guidelines (USEPA 1985) as described above in section 5.5.3. There were sufficient data to derive acute criteria for bifenthrin, cypermethrin, lambda-cyhalothrin, and permethrin. The acute data sets for these four pyrethroids met seven of eight taxa requirements, but an exception was made because the missing taxon (a phylum not already represented, e.g., a mollusk) is known to be insensitive to pyrethroids, which was also done in the CDFW hazard assessment (section 5.5.3). There were sufficient data to calculate an acute-to-chronic ratio and a chronic criterion for lambda-cyhalothrin, but chronic criteria could not be calculated for any other pyrethroids.

Table 5-9 Water quality criteria derived following the USEPA guidelines (USEPA 1985) All concentrations in μg/L.

Pesticide	**Criterion maximum concentration (acute)**	**Criterion continuous concentration (chronic)**
Bifenthrin[a]	0.059	Not calculable
Cyfluthrin	Not calculable	Not calculable
Cypermethrin[b]	0.25	Not calculable
Esfenvalerate	Not calculable	Not calculable
Lambda-cyhalothrin[c]	0.21	0.087
Permethrin[d]	4	Not calculable

[a]Fojut 2015a; [b]Fojut 2015c; [c]Fojut 2015e; [d]Fojut 2015f.

The criteria derived using the USEPA method are lower than the water quality criteria derived using the 5th percentile of the SSD in the UC Davis method (section 5.5.6), but are higher than the criteria that include protection for sensitive species (section 5.5.5), except for bifenthrin. The bifenthrin acute criterion of 0.06 ng/L derived using the 1st percentile is approximately equal to the criterion maximum concentration of 0.059 ng/L.

While chronic criteria are not available for five of the six pyrethroids, and acute criteria are available for four of the six pyrethroids, this alternative will be further considered because the values are protective of the most sensitive species in current data sets and uses USEPA methodology, which would be consistent with Clean Water Act guidance for developing water quality standards.

5.5.8 Pyrethroid Working Group combined species sensitivity distribution for acute toxicity of pyrethroids to arthropods

The Pyrethroid Working Group (PWG) is an industry consortium of pyrethroid registrants (manufacturers) that works collaboratively to produce research and assessments on pyrethroids to meet pesticide registration requirements of USEPA and CDPR. As part of an ecological risk assessment for the USEPA registration review of pyrethroids, the PWG produced a species sensitivity distribution for acute toxicity to arthropods with data from nine pyrethroids (Giddings et al. 2014). This assessment includes the six pyrethroids identified in the proposed Bain Plan amendment.

To create a combined pyrethroids species sensitivity distribution, acute toxicity data for 107 arthropod species were normalized to a single scale so they could be plotted together. The acute toxicity data for nine pyrethroids were normalized to *Hyalella azteca* equivalents by dividing the LC_{50} for a given species and pyrethroid by the LC_{50} for *Hyalella azteca* for that same pyrethroid. The *Hyalella azteca* equivalents were plotted and a logistic regression SSD was fit to the data. The 5th percentile of this distribution (HC5) was determined to be 5.31 *Hyalella azteca* equivalents (Giddings et al. 2014).

The PWG report did not derive water quality criteria, but water quality criteria can be calculated based on an HC5. Following the general guidelines of the USEPA method (USEPA 1985), acute water quality criteria were calculated by dividing the 5th percentile value (HC5) by 2. For this calculation, the HC5 based on *Hyalella azteca* equivalents was first converted to a concentration for each of the six pyrethroids, and then that concentration was divided by 2 (Table 5-10).

The PWG SSD approach only provides acute water quality criteria and does not address chronic effects on aquatic organisms. The water quality criteria generated from the combined pyrethroids SSD would not be protective of the sensitive species *Hyalella azteca* or several other species based on the data used in the assessment (i.e., the water quality criteria are higher than the LC_{50}s for these organisms). In the USEPA and UC Davis methods, the 5th percentile is used because it is usually a good approximation of a no-effect level, particularly for small to moderate-sized data sets. Because the data set was so large in the PWG combined pyrethroids SSD, the 5th percentile is not an approximation of a no-effect level, but instead is a value that toxicity data for approximately 5% of the species fall below. Because this approach does not provide protection from chronic effects and does not appear to be protective of the most sensitive species in the data set used, these values will not be further considered for use as water quality objectives.

Table 5-10 Calculation of water quality criteria based on PWG combined pyrethroid SSD.

Hyalella azteca equivalents HC5[a]: 5.31 (4.16-6.79)				
	Hyalella azteca LC_{50} (μg/L)[a]	HC5 concentration (μg/L)	Acute water quality criteria (HC5/2) (μg/L)	Acute water quality criteria (ng/L)
Bifenthrin	0.00050	0.00266	0.0013	1.3
Cyfluthrin	0.00055	0.0029	0.0015	1.5
Cypermethrin	0.00118	0.0059	0.0030	3.0
Esfenvalerate	0.00085	0.0045	0.0023	2.3
λ-cyhalothrin	0.00030	0.0016	0.00080	0.8
Permethrin	0.0070	0.037	0.019	19

[a]*Hyalella azteca* equivalents HC5 and *Hyalella azteca* LC_{50} from Giddings et al. 2014.

5.5.9 Australia/New Zealand trigger

There is a trigger value of 1 μg/L available for esfenvalerate. The data source and methodology for determining this value is not readily available in the report in which the trigger is cited (ANZECC/ARMCANZ 2000), thus this value will not be further considered for use as a water quality objective.

5.5.10 Canadian Interim Freshwater Quality Guidelines

Environment Canada has reported an interim freshwater quality guideline for permethrin of 4 ng/L (CCME 2006). This interim freshwater quality guideline was derived using a chronic toxicity value of 0.042 μg/L for the stonefly *Pteronarcys dorsata* (Anderson 1982). This chronic toxicity value was multiplied by a safety factor of 0.1 to derive the interim freshwater guideline of 4 ng/L (0.0042 μg/L). The freshwater quality guideline is referred to as "interim" because the minimum data requirements were not met to derive a full water quality guideline. High quality toxicity values were available from a chronic fish study and a chronic invertebrate study, however, high quality chronic toxicity values were missing for a second fish species, a second class of invertebrates, and an algae. The Canadian interim freshwater quality guideline for permethrin will not be further considered because only a chronic value is available for one of six pyrethroids.

5.5.11 Dutch Maximum Permissible Concentrations

The Dutch environmental agency has derived what could be considered chronic criteria for several pyrethroids, which they term maximum permissible concentrations (MPCs). Because chronic data for four species (the minimum data sets for the Dutch method) were not available for any of the pyrethroids they assessed, the MPCs were derived by dividing the lowest toxicity value by an assessment factor (Crommentuijn et al. 2000). In the Dutch method, the magnitude of the assessment factor is dependent on the available toxicity data. If a NOEC for chronic toxicity is available, it is divided by an assessment factor of 10, if acute toxicity values are available that fulfill the minimum data set, the lowest value is divided by a factor of 100. If the minimum data set is not available and no chronic data is available, then the lowest acute toxicity value is divided by a factor of 1000 to determine the MPC. The toxicity values and the magnitude of the assessment factors used to derive the MPCs for bifenthrin, cypermethrin and permethrin are not described in the Dutch environmental agency reports or publications. Because of the lack of readily available information regarding the data used to derive the MPCs, these values will not be further considered for use as water quality objectives.

5.5.12 USEPA Office of Pesticide Programs Aquatic Life Benchmarks

USEPA Office of Pesticide Programs (OPP) aquatic life benchmarks are available for all six priority pyrethroids, as well as several other pyrethroids. These benchmarks were derived in order to assist states in interpreting pesticide monitoring data, but were not intended for use as water quality criteria (USEPA 2012a). Acute aquatic life benchmarks for fish and invertebrates are derived by multiplying the most sensitive, scientifically acceptable acute toxicity endpoint identified by USEPA OPP for a given taxon by a level of concern of 0.5. Chronic aquatic life benchmarks are equal to the most sensitive chronic toxicity value identified by USEPA OPP, which is typically a no-observed adverse effect concentration (NOAEC). Acute benchmarks for plants are equal to the short-term EC_{50}.

The most sensitive benchmarks for all six pyrethroids are the chronic invertebrate benchmarks are given in Table 5-11. All of the acute invertebrate benchmarks are Acute and chronic USEPA OPP aquatic life benchmarks are available for all six pyrethroids, but the acute benchmarks all exceed *Hyalella azteca* LC_{50}s (shown in Table 5-6). USEPA also explains that the OPP aquatic life benchmarks are not intended for use as water quality criteria, so this alternative would not be consistent with USEPA guidance. Thus, this alternative will not be further considered.

Table 5-11 US EPA Office of Pesticide Program aquatic life benchmarks (USEPA 2012a).
All concentrations in ppb (µg/L).

Pesticide	Fish		Invertebrates		Nonvascular Plants
	Acute	Chronic	Acute	Chronic	Acute
Bifenthrin	0.075	0.04	0.8	0.0013	n/a
Cyfluthrin	0.034	0.01	0.0125	0.0074	>181
Cypermethrin	0.195	0.14	0.21	0.069	n/a
Esfenvalerate	0.035	0.035*	0.025	0.017	n/a
Lambda-cyhalothrin	0.105	0.031	0.0035	0.002	>310
Permethrin	0.395	0.0515	0.0106	0.0014	68

*Because the lowest chronic NOAEC available was higher than the acute LC_{50}, the chronic fish benchmark was estimated using an acute-to-chronic ratio of 2.0 applied to the LC_{50} of 0.07 ppb for rainbow trout. The acute-to-chronic ratio was calculated from an acute LC_{50} and chronic NOAEC for fathead minnow. (USEPA 2008)

5.6 Sediment Concentrations – Water Quality Objective Alternatives

There are three alternatives considered for establishing water quality objectives for pyrethroids in sediment:

1. No change in water quality objectives (continue to interpret narrative objectives);
2. No pyrethroids in sediments;
3. No-effect level
    a. Maximum acceptable toxicant levels, or
    b. Sediment quality criteria.

Each alternative is described and evaluated based on its scientific validity and robustness as well as Porter-Cologne considerations and other applicable laws and policies. Section 13241 of Porter-Cologne specifies the following considerations in establishing water quality objectives: 1) past, present, and probable future beneficial uses of water, 2) environmental characteristics of hydrographic unit, including quality of water available to it, 3) water quality conditions reasonably achievable through coordinated control of all factors that affect water quality in the area, 4) economic considerations, 5) the need for developing housing within the region, and 6) the need to develop and use recycled water. Each of these alternatives would be applied by considering pyrethroid toxicity additively.

Sediment quality criteria for the protection of aquatic life have not been derived for many current-use pesticides, and in fact, there are very few jurisdictions that even have a methodology to derive sediment quality criteria (Fojut et al. 2011, 2013). Because humans have little contact with sediments and we have no information regarding human health effects from contact with pyrethroid-contaminated sediments, we are assuming that the freshwater habitat beneficial uses (WARM/COLD) are the most sensitive to pyrethroids in sediments. Table 5-12 contains available numeric thresholds for pyrethroids in sediments for the protection of aquatic life.

Table 5-12 Available sediment quality criteria and guidelines for pyrethroids

	Bifenthrin	Cyfluthrin	Lambda-Cyhalothrin	Cypermethrin	Esfenvalerate	Permethrin
Aquatic life criteria for freshwater sediments						
Evaluation guidelines used in 2010 update of 303(d) list – Central Valley Region[a]	0.52 µg/g OC	1.08 µg/g OC	0.45 µg/g OC	0.38 µg/g OC	1.54 µg/g OC	10.83 µg/g OC
Evaluation guidelines proposed for 2012 update of 303(d) list[b]	0.43 µg/g OC[c,d]	1.1 µg/g OC[c]	0.44 µg/g OC[c]	0.3 µg/g OC[e]	1.5 µg/g OC[c]	8.9 µg/g OC[c]
Dutch maximum permissible concentration[f] (chronic criterion)	4.8 µg/kg DW (0.048 µg/g OC)	NA	NA	0.39 µg/kg DW (0.0039 µg/g OC)	NA	0.87 µg/kg DW (0.0087 µg/g OC)
ESG_{OC} based on chronic UCD WQC	0.6 µg/g OC	0.1 µg/g OC	0.9 µg/g OC	0.4 µg/g OC	0.1 µg/g OC	3 µg/g OC
ESG_{OC} based on chronic USEPA WQC (CCC)	NA	NA	0.74 µg/g OC	NA	NA	NA

NA: not available; OC: organic carbon; DW: dry weight; ESGOC: OC-normalized equilibrium sediment guideline. Sources: [a]10-day sediment LC_{50} for *Hyalella azteca* (SWRCB 2010); [b]10-day sediment LC_{50} for *Hyalella azteca* (CRRWQCB 2014); [c]Amweg et al. 2005, [d]Amweg and Weston 2007; [e]Maund et al. 2002; [f]Crommentuijn et al. 2000.

5.6.1 **No Change in Water Quality Objectives**

The Basin Plan currently contains narrative water quality objectives regarding pesticides and toxicity. The Central Valley Water Board uses available guidelines and criteria to interpret existing narrative water quality objectives. The Central Valley Water Board has not established criteria specifically for pyrethroids to interpret compliance with its narrative water quality objectives for toxicity and pesticides.

In the past, such as on the 2010 update to the 303(d) list, sediment toxicity due to pyrethroids has been identified as impairing water bodies. In these cases, demonstration of statistically significant toxicity compared to controls was used to interpret the narrative toxicity water quality objective (i.e., "no toxics in toxic amounts"). Sediment chemistry data have been interpreted using a toxicity unit analysis, in which sediment concentrations normalized to organic carbon content of the sediment were compared to OC-normalized LC_{50}s for sediment-bound pyrethroids. The evaluation guidelines used to interpret pyrethroid sediment concentrations may change as new toxicity information becomes available, so the LC_{50}s used in the past may not always be the numeric evaluation guidelines in the future. The "no change" alternative will be further considered for pyrethroids because it would apply if numeric objectives for sediments were not established.

5.6.2 **No Pyrethroids in Sediments**

The Central Valley Water Board could adopt water quality objectives that would maintain "natural" water quality conditions. Water quality objectives based on these conditions would mean that detectable levels of pyrethroids in sediments would not be allowed. California's antidegradation policies allow for the presence of pyrethroids if that presence is consistent with maximum benefit to the people of the state, and does not unreasonably affect present and anticipated beneficial uses, and does not result in water quality less than that prescribed in existing policies (State Water Board Resolution 68-16 and 40 CFR 131.12).

The Central Valley Water Board could make a determination that allowing the presence of any pyrethroids in sediments is not to the maximum benefit of the people of the state, which would serve as the basis for a no pyrethroids objective for sediment. Alternatively, the Central Valley Water Board could determine that allowing the presence of some pyrethroids in sediments is consistent with the maximum benefit to the people of the state, but that the concentration consistent with the maximum benefit is less than the highest concentration that would be protective of beneficial uses.

This alternative will be further considered because antidegradation policies allow the Central Valley Water Board to make a determination that the presence of any pyrethroids in sediments in any Sacramento or San Joaquin River basin water body is not to the maximum benefit of the people of the state.

5.6.3 **No-effect level**

Two ways to predict or estimate no-effect levels were identified: 1) the use of single species maximum acceptable toxicant concentrations (MATCs) and 2) the use of sediment quality criteria (SQC). No-effect levels were identified as an alternative because they are in accordance with the narrative toxicity water quality objective in the Basin Plan.

5.6.3.1 MATCs

Maximum acceptable toxicant concentrations are toxicity values from single-species laboratory toxicity tests. MATCs are typically calculated as the geometric mean of the no-observed effect concentration and the lowest-observed effect concentration. The MATC is an approximation of a no-effect level for the tested species, but is not necessarily the no-effect level for all species in an aquatic ecosystem. If the test species is the most sensitive species in an ecosystem, then the MATC should be protective of the entire ecosystem. MATCs are available for the priority pyrethroids for at least two species (Table 5-13). When more than one MATC is available, the value for the most sensitive species would be chosen. This alternative will be further considered because these values would likely be more protective of aquatic ecosystems than those used to interpret the narrative objectives in the recent past, which were LC_{50}s, and they are available for sensitive species for all six priority pyrethroids.

Table 5-13 Sediment-based MATCs available for the priority pyrethroids

Chemical	**Species**	**Endpoint**	**OC-normal MATC (μg/g OC)[a]**	**Reference**
Bifenthrin	*Hyalella azteca*	10 d Growth	**0.03***	Picard 2010a
	H. azteca	10 d Survival	0.12	Picard 2010a
	Chironomus dilutus	10 d Survival	6.45	Picard 2010b
Cyfluthrin	*H. azteca*	10 d Growth	**0.015***	Picard 2010c
	H. azteca	10 d Survival	0.063	Picard 2010c
	C. dilutus	10 d Survival	0.85	Picard 2010d
Cypermethrin	*H. azteca*	10 d Growth	0.12	Picard 2009a
			0.40	Picard 2009c
			0.61	Picard 2009d
			0.13	Picard 2009e
			0.25*	Geometric Mean
	H. azteca	10 d Survival	0.21	Picard 2009a
			0.79	Picard 2009b
			0.75	Picard 2009c
			1.18	Picard 2009d
			0.65	Picard 2009e
			0.080	Picard 2010f
			0.44	Geometric Mean
	C. dilutus	10 d Survival	2.03	Picard 2010g
Esfenvalerate	*H. azteca*	10 d Survival	**0.24***	Picard 2010h
	C. dilutus	10 d Survival	7.69	Picard 2010i
Lambda-cyhalothrin	*H. azteca*	10 d Survival	**0.054***	Picard 2010j
	C. dilutus	10 d Growth	1.09	Picard 2010k
	C. dilutus	10 d Survival	2.10	Picard 2010k
Permethrin	*H. azteca*	10 d Growth	**0.43***	Picard 2010l
	H. azteca	10 d Survival	1.61	Picard 2010l
	C. dilutus	10 d Survival	7.74	Picard 2010m

[a] Calculated as the geometric mean of the reported NOEC and LOEC divided by the reported OC content.
* Indicates the MATC for the most sensitive species-endpoint for each chemical.

5.6.3.1 Sediment Quality Criteria

Sediment quality criteria are analogous to water quality criteria. For both types of criteria the goal is to approximate a no-effect level for all species in an ecosystem using data from multiple species, if they are available. Using sediment quality criteria as objectives would be preferable to using MATCs because SQC are designed to be protective of the entire ecosystem, whereas MATCs are only known to be protective of a single species.

UC Davis developed a draft methodology for derivation of sediment quality criteria (Fojut et al. 2014), but the methodology has not been finalized. To test the method, UC Davis used the methodology to derive sediment quality criteria for three pyrethroids (bifenthrin, permethrin, and esfenvalerate), and in this process found that so little sediment toxicity data were available for these compounds that the methodology could not be fully vetted. Thus, the sediment quality criteria for these compounds are termed interim values to indicate that it is not yet clear whether the method produces criteria that are likely to be protective of all species in aquatic ecosystems. The UC Davis methodology and interim criteria will not be further considered because of the high level of uncertainty in the interim criteria and the draft methodology.

There are sediment quality criteria available from the Dutch National Institute of Public Health and the Environment, termed maximum permissible concentrations ($MPC_{sediment}$), which are analogous to chronic criteria (Crommentuijn et al. 2000). These values are available for three of the priority pyrethroids: bifenthrin, cypermethrin, and permethrin (Table 5-12). These values were calculated using the equilibrium partitioning approach, which is determined using the water quality criteria (termed MPC_{water} in the Dutch documents) and the solid-water partition coefficient (K_d). In the Dutch report, the following equation was used to calculate MPC's in sediment:

Equation 5

$$MPC_{sediment} = MPC_{water} * K_d$$

The specific toxicity values used to calculate the MPC_{water} values were not reported (section 5.5.11), and the individual values and sources are not reported for the solid-water partition coefficients used to calculate the $MPC_{sediment}$ values. Because it is not possible to review these data sources, the Dutch $MPC_{sediment}$ values will not be further considered.

The US EPA proposed a similar equilibrium partitioning approach as used in the Dutch method (USEPA 2002); however values were normalized to the organic carbon content of the sediment as follows:

Equation 6

$$ESG_{OC} = FCV * K_{OC}$$

Where:
ESG_{OC} = organic carbon-normalized equilibrium sediment guideline
FCV = final chronic value from the US EPA water criteria method (USEPA 1985; FCV is typically equivalent to the chronic water quality criterion)
K_{OC} = organic carbon-normalized sediment-water partition coefficient

Equation 6 was used to calculate sediment criteria (or guidelines) based on equilibrium partitioning. The ESG_{OC} values were calculated with both the 2015 chronic water quality criteria derived with the UC Davis method (section 5.5.5) and the lambda-cyhalothrin chronic criterion calculated using the EPA method with the UC Davis data set (section 5.5.7). The K_{OC} values used to calculate the ESG_{OC} values are the median values given in Table 5-5, and are also provided in Table 5-14.

Table 5-14 Equilibrium sediment guidelines normalized to organic carbon (ESG_{OC}) for six pyrethroids

	Bifenthrin	Cyfluthrin	Cypermethrin	Esfenvalerate	Lambda-cyhalothrin	Permethrin
K_{OC}[a]	1,757,059	3,389,903	2,726,695	5,832,845	2,108,975	4,129,607
2015 chronic criteria via UCD (ng/L)[b]	0.01	0.01	0.01	0.03	0.01	1
2015 chronic criteria via USEPA (ng/L)[b]					0.087	
ESG_{OC} based on UCD criteria (μg/g OC)	0.02	0.03	0.03	0.2	0.02	4
ESG_{OC} based on USEPA criteria (μg/g OC)					0.18	
Hyalella azteca LC_{50} (μg/g OC)[c]	0.43	1.08	0.34	1.53	0.45	8.68
Lowest MATC (μg/g OC)[d]	0.03	0.015	0.25	0.054	0.24	0.43

[a]See Table 5-5, [b]See Table 5-7, [c]See Table 5-6, [d]See Table 5-13.

The ESG_{OC} values can be compared to sediment LC_{50} values (also given in Table 5-6) and MATCs (Table 5-13) to assess whether the ESG_{OC} values would likely be protective of aquatic organisms. This comparison is important because the ESG_{OC} values are calculated based on water column toxicity data, and comparing the values to known sediment data provides a way to ensure that the overall calculation approach is valid for these data sets. All of the ESG_{OC} values are lower than the sediment LC_{50} values, indicating that the ESG_{OC} values would likely be protective of known sensitive species. The lowest MATCs for two pyrethroids (cyfluthrin and permethrin) are lower than the ESG_{OC} values derived using the chronic criteria from the UC Davis method and the lowest MATC for lambda-cyhalothrin is lower than the ESG_{OC} value derived using the chronic criterion from the USEPA method, indicating that using water column toxicity data may not be protective of sediment species for these compounds. Based on this data comparison, it appears that the calculated ESG_{OC} may not be protective of sensitive aquatic organisms and thus ESG_{OC} are not recommended for further consideration as water quality objectives.

5.7 Summary of Potential Water Quality Objectives Derived by Alternate Methods

The alternatives that are further considered as potential water quality objectives for pyrethroids are summarized below. In the following section, these remaining alternatives are evaluated with respect to Porter-Cologne requirements and other applicable laws and policies. The alternative potential water quality objectives are summarized in Table 5-15 and Table 5-16 for the aqueous pyrethroids and sediment-bound pyrethroids, respectively. For either matrix, objectives for the six pyrethroids do not all need to be selected from the same alternative.

5.7.1 Aqueous concentrations alternatives

The “No change” alternative would not establish numeric water quality objectives for pyrethroids in the Sacramento and San Joaquin River basin water bodies. Instead, the best available technical information would continue to be used to interpret the narrative water quality objectives. Under this alternative, the numeric evaluation guidelines can change over time as the state of science evolves.

The “No pyrethroids” alternative would establish no detectable concentrations of any individual pyrethroid in the water column as water quality objectives.

The 2015 water quality criteria derived via University of California Davis method alternative would establish numeric water quality objectives including the six pyrethroids of interest (bifenthrin, cyfluthrin, cypermethrin, esfenvalerate, lambda-cyhalothrin, and permethrin) (section 5.5.4). Under this alternative, the six pyrethroids would be considered additively and measured or estimated freely dissolved concentrations could be used to determine whether the objectives are attained.

The 2015 water quality criteria derived via USEPA method alternative, the acute water quality objectives for bifenthrin, cypermethrin, lambda-cyhalothrin, and permethrin would be the criteria calculated using the USEPA method and the 2015 data sets (section 5.5.7). Criteria are not available for cyfluthrin and esfenvalerate under this alternative, so values from a different alternative would be needed for the objectives for these compounds. Chronic criteria are not available for five of the six pyrethroids under this alternative, thus only the lambda-cyhalothrin chronic criterion could be used in a chronic water quality objective under this alternative and values from another alternative would be needed for the other five pyrethroids. Under this alternative, the six pyrethroids would be considered additively and measured or estimated freely dissolved concentrations could be used to determine whether the objectives are attained.

Table 5-15 Summary of water quality objective alternatives – Aqueous concentrations (ng/L)

Alternative	No Change	No pyrethroids	2015 criteria via UC Davis method		2015 criteria via USEPA method	
			Acute	Chronic	Acute	Chronic
Bifenthrin	Best available technical value	No detectable pyrethroids	0.06	0.01	0.059	--
Cyfluthrin			0.07	0.01	--	--
Cypermethrin			0.04	0.01	0.25	0.087
Esfenvalerate			0.2	0.03	--	--
Lambda-cyhalothrin			0.03	0.01	0.21	--
Permethrin			6	1	4	--

5.7.2 **Sediment concentrations alternatives**

The “No change” alternative for sediment concentrations would not establish numeric water quality objectives for sediment-bound pyrethroids in the Sacramento and San Joaquin River basin water bodies. Instead, the best available technical information would continue to be used to interpret the narrative water quality objectives. Under this alternative, the numeric evaluation guidelines can change over time as the state of science evolves.

The “No pyrethroids” alternative would establish no detectable concentrations of any individual pyrethroid in sediments as water quality objectives.

For the no-effect level MATC alternative for sediment would establish numeric objectives for the six pyrethroids in sediment (section 5.6.3.1). Under this alternative, the six pyrethroids would be considered additively.

Table 5-16 Summary of water quality objective alternatives – Sediment concentrations (µg/g OC)

Alternative	No Change	No pyrethroids	No-effect level MATC (µg/g OC)[a]
Bifenthrin	Best available technical value	No detectable pyrethroids	0.03
Cyfluthrin			0.015
Cypermethrin			0.25
Esfenvalerate			0.24
Lambda-cyhalothrin			0.054
Permethrin			0.43

[a]See Table 5-13 for MATC references.

5.8 Evaluation of Water Quality Objective Alternatives

This section evaluates the alternatives for establishing water quality objectives with respect to the Porter-Cologne Water Quality Control Act and other applicable state and federal laws and policies. Section 13241 of Porter-Cologne specifies the following considerations in establishing water quality objectives:

1. Past, present, and probable future beneficial uses of water.
2. Environmental characteristics of hydrographic unit, including quality of water available to it.
3. Water quality conditions reasonably achievable through coordinated control of all factors that affect water quality in the area.
4. Economic considerations.
5. The need for developing housing within the region.
6. The need to develop and use recycled water.

Table 5-17 and Table 5-18 present qualitative assessments of the alternate methods for water column and sediment, respectively, for their consistency with Porter-Cologne and other state and federal requirements. The rationale for the assessment of each method follows the tables.

Table 5-17 Water Quality Objectives – Aqueous Concentrations: Assessment Alternatives for Consistency with Porter-Cologne and other State and Federal Requirements

	No Change	**No Pyrethroids**	**2015 criteria via UC Davis method**	**2015 criteria via USEPA method**[1]
Porter-Cologne Requirements				
Beneficial Uses	-	+	+	+
Environmental Characteristics	0	0	0	0
Conditions Reasonably Achievable	-	-	-	-
Economic Considerations	+	-	+	+
Need for Housing	0	0	0	0
Need to Recycle Water	+	+	+	+
State and Federal Laws and Policies				
Antidegradation	C	C	C	C
Clean Water Act	C	C	C	C
ESA	C	C	C	C

[1] Only applicable to bifenthrin, lambda-cyhalothrin, and permethrin.

Scores indicate relative degree of protection; attainability; achievability; impact or consistency with policy, as applicable, with 0 indicating neutral:

Beneficial Uses: Not protective of beneficial uses: -
Fully protective: +

Environmental Characteristics: Not attainable: -
Fully attainable: +

Achievability: Difficult to achieve: -
Readily achievable: +

Economic Considerations: Potentially significant impact: -
Modest or no negative impact: +

Housing: Significant housing impact: -
Little or no impact: +

Recycling Water: Significant impact on recycling water: -
Little or no impact: +

C = Consistent

Table 5-18 Water Quality Objectives – Sediment: Assessment Alternatives for Consistency with Porter-Cologne and other State and Federal Requirements

	No Change	No Pyrethroids	No-effect level: MATC
Porter-Cologne Requirements			
Beneficial Uses	-	+	+
Environmental Characteristics	0	0	0
Conditions Reasonably Achievable	-	-	-
Economic Considerations	+	-	+
Need for Housing	0	0	0
Need to Recycle Water	0	0	0
State and Federal Laws and Policies			
Antidegradation	C	C	C
Clean Water Act	C	C	C
ESA	C	C	C

Scores indicate relative degree of protection; attainability; achievability; impact or consistency with policy, as applicable, with 0 indicating neutral:

Beneficial Uses: Not protective of beneficial uses: -
Fully protective: +

Environmental Characteristics: Not attainable: -
Fully attainable: +

Achievability: Difficult to achieve: -
Readily achievable: +

Economic Considerations: Potentially significant impact: -
Modest or no negative impact: +

Housing: Significant housing impact: -
Little or no impact: +

Recycling Water: Significant impact on recycling water: -
Little or no impact: +

C = Consistent

5.8.1 **Beneficial Uses**

Federal law requires that states adopt criteria that protect the beneficial uses and that the most sensitive uses are protected. (40 C.F.R. § 131.11(a).) In addition, state law requires the reasonable protection of beneficial uses and that those beneficial uses are considered in establishing water quality objectives. (Wat. Code, § 13241, et seq.) In this section, each potential objective is evaluated for the requirement to protect beneficial uses.

5.8.1.1 Aqueous concentrations

5.8.1.1.1 *No Change in Water Quality Objectives*

The Basin Plan's narrative water quality objectives for pesticides and toxicity provide direction in terms of protecting beneficial uses (i.e., toxicity is not allowed). In the last update to the 303(d) list, there was one water column listing for the pyrethroid cis-permethrin and one water column listing for the pyrethroid bifenthrin. For the cis-permethrin listing, one-tenth of a LC_{50} for *Tanytarsus sp*. was used as the evaluation guideline. For the bifenthrin listing, the evaluation guideline was one-tenth of a LC_{50} for *Hyalella azteca*. The CDFW interim criteria for permethrin and cypermethrin were also used as evaluation guidelines, although there were no listings for these compounds based on the data available during that 303(d) list update. Future water column data evaluations will likely use the UC Davis criteria as evaluation guidelines (CRRWQCB 2014) because they were derived to be protective of aquatic life and are consistent with the evaluation guidelines given in the Water Quality Control Policy for Addressing Impaired Waters (section 6.1.3 in SWRCB 2004). If water column toxicity test data is available, data would be evaluated based on significant statistical difference from the control water.

When attainment of the narrative objectives are assessed under the "no change" alternative, the most current toxicity data or water quality criteria would be used for assessing attainment, which would be fully protective of beneficial uses. However, it should be noted that assessment of the narrative objectives specifically for pyrethroids may not be required by some regulatory programs because there are many ways to assess attainment of narrative objectives. In contrast, when numeric objectives are established, many regulatory programs have requirements that dischargers must assess whether they may be causing or contributing to exceedances of those numeric objectives.

5.8.1.1.2 *No Pyrethroids*

Water quality objectives based on no pyrethroids would be highly protective of beneficial uses, since there would be no potential risk to beneficial uses from these chemicals in the water column.

5.8.1.1.3 *2015 Criteria via UC Davis Method*

Similar to the USEPA criteria method, the UC Davis method uses acute and chronic toxicity data for a wide range of species. The criteria derived using the UC Davis method are expressed in the same averaging period (hourly and 4-day) and allowable exceedance frequency (once every three years) as is used in the USEPA method. The 2015 criteria generated using the UC Davis method would be protective of *Hyalella azteca* and other sensitive species based on current toxicity data. Therefore, the UC Davis criteria are expected to be protective of all freshwater habitat uses in the Sacramento and San Joaquin River basin water bodies.

5.8.1.1.4 *2015 Criteria via USEPA method*

Criteria were derived using the USEPA method and the acute and chronic toxicity data sets gathered as part of the derivation of 2015 criteria using the UC Davis method. The criteria are designed to be protective of the most sensitive aquatic organisms and the acute and chronic criteria are designed to avoid detrimental physiologic responses. Water quality criteria derived with the USEPA method could only be derived for four of the six pyrethroids of interest (bifenthrin, cypermethrin, lambda-cyhalothrin, and permethrin). In addition, a chronic criterion could only be derived for lambda-cyhalothrin. These values are not approved or promulgated by USEPA, but were derived by following the USEPA method with the exception that the data sets used to derive them were incomplete. The criteria were derived with incomplete data sets because the only missing taxon is known to be particularly insensitive to pyrethroids, and the lack of the taxon would not lead to an underestimation of toxic effects. This practice was consistent with the CDFW interim criteria that were derived for several pyrethroids. These criteria would be protective of *Hyalella azteca* and other sensitive species based on current toxicity data. These criteria are expected to be protective of all freshwater habitat uses in the Sacramento and San Joaquin River basin water bodies for the compounds and averaging periods for which they are available, however, to protective aquatic life beneficial uses from all six pyrethroids, acute values from a different alternative would be needed for the remaining two pyrethroids and for chronic averaging periods for the remaining five pyrethroids.

5.8.1.2 Sediment

5.8.1.2.1 *No Change in Water Quality Objectives*

There were 14 listings for sediment toxicity caused by pyrethroids on the 2010 update to the 303(d) list. The evaluation guideline used for these listings was a statistically significant difference between the sample and control sediments using Dunnett's test in 10-day *Hyalella azteca* sediment toxicity tests. To evaluate sediment chemistry data, laboratory sediment toxicity values (LC_{50}s) for *Hyalella azteca* were used. With no change in the water quality objectives, numeric evaluation guidelines protective of the most sensitive beneficial use would continue to be used to interpret the narrative water quality objectives. It appears that the WARM/COLD beneficial uses are the most sensitive to pyrethroids, thus, the evaluation guidelines should be at a level expected to be protective of freshwater habitat uses. Toxicity values are available for all six pyrethroids for *Hyalella azteca*, which is known to be particularly sensitive to pyrethroids, and if these toxicity values are used as the evaluation guidelines, then they should be protective of acute effects on benthic species. If sediment toxicity test data is available, data would be evaluated based on significant statistical difference from the control. The “no change” option would be fully protective of beneficial uses because the most current toxicity data would be used for assessing attainment with the narrative objectives as well as toxicity test results that would demonstrate whether these data are predictive of ambient toxicity.

Similarly to the water column “no change” alternative, there are more regulatory requirements to assess attainment with specific numeric objectives compared to narrative objectives. Thus, the “no change” alternative may not be as protective of beneficial uses compared to adopting numeric objectives for pyrethroids in sediment.

5.8.1.2.2 *No Pyrethroids*

Sediment objectives based on no pyrethroids would be highly protective of beneficial uses, since there would be no potential risk to beneficial uses from these chemicals in sediments.

5.8.1.2.3 *No-effect Level (MATC)*

MATCs are likely to be protective of the WARM/COLD beneficial uses if the available values are for sensitive species, such as *Hyalella azteca.* MATCs are available for the six priority pyrethroids from tests with *H. azteca*, thus it is likely that these values would be protective of all aquatic life in the Sacramento and San Joaquin River basin water bodies.

5.8.2 **Environmental Characteristics and Quality of Water Available**

Pyrethroids enter the Sacramento and San Joaquin River basin water bodies from applications to a variety of crops in the Central Valley and from applications in urban areas by both licensed pesticide applicators and homeowners. None of the alternate methods of deriving water quality objectives for either the water column or sediment are dependent on any natural environmental characteristic. Pyrethroids are not naturally-occurring pollutants; therefore background levels of these pesticides are not expected in absence of their use. All of the potential criteria are, therefore, equally consistent with the environmental characteristics of the watershed. However, environmental characteristics may alter the toxic potential or bioavailability of pyrethroids. Concerns have also been raised about the environmental relevance of using the test organism *Hyalella azteca* to calculate water quality criteria or test for toxicity in ambient samples because some field populations have been identified that are highly resistant to pyrethroids. Bioavailability is discussed in section 5.3 and resistant populations of *Hyalella azteca* are discussed in section 5.4.

5.8.3 Water Quality Conditions Reasonably Achievable

Pyrethroid concentrations detected in the Sacramento River and San Joaquin River basin water bodies are the result of current-year applications of these pesticides. Unlike DDT or certain other chlorinated pesticides, pyrethroids are only moderately persistent in the aqueous environment, but similarly to chlorinated pesticides, they are sequestered in sediments. Unlike some naturally occurring compounds such as selenium, there are no natural sources of pyrethroids, and there are no natural, or "background" concentrations. If these pesticides were prevented from entering surface waters, then concentrations of pyrethroids in surface waters and sediments would decline relatively rapidly because for most pyrethroids aerobic degradation half-lives are 2 months or less (Meyer et al. 2013). The pyrethroid bifenthrin does have a longer aerobic degradation half-life than the other pyrethroids (at least 3 months; Meyer et al. 2013), and more time may be needed for the environmental levels of this compound to be reduced to levels that are protective of aquatic life.

The difficulty and cost of preventing pyrethroids from entering surface waters are key elements in achieving the water quality objectives for these pesticides. Options for reducing the amount of pesticides entering the water bodies in the Sacramento River and San Joaquin River basin are discussed in section 7. Table 5-19 and Table 5-20 compare pyrethroids monitoring data to the alternate acute and chronic water quality objectives for aqueous concentrations. Based on the available monitoring data, significant reductions in pyrethroid discharges are needed in all water body types to attain water quality criteria derived by either the UC Davis or USEPA method (Table 5-19 and Table 5-20). However, it should be noted that all of the monitoring data used to compare to the water quality criteria are based on whole water concentrations. It is likely that the reductions needed to attain the water quality criteria would be much lower if they were compared to freely dissolved concentrations.

For water bodies receiving urban storm water discharges, the recently adopted CDPR surface water regulations are expected to result in significant reductions in pyrethroids entering surface waters. One study modeled the effects of the CDPR surface water regulations in the urban watershed of the lower American River in Sacramento (Jorgenson et al. 2013). The model predicted that if the surface water regulations are fully implemented, there would be an 84% reduction in pyrethroid levels in this watershed (reported as pyrethroid toxic units). The average reductions needed to attain the chronic UC Davis criteria in urban or mixed watersheds range from 0-100%, depending on the pyrethroid (Table 5-20). Jorgenson et al. (2013) state that the majority (~70%) of pyrethroid toxic units in the watershed are associated with bifenthrin and cyfluthrin, for these two compounds, reductions of 100% are needed in urban watersheds to attain the chronic criteria derived by the UC Davis method. While the 84% reduction expected as a result of the CDPR surface water regulations may not completely eliminate exceedances of water quality criteria, they are expected to make a significant impact in reducing toxicity related to pyrethroids.

Table 5-19 Reductions needed to attain acute criteria during exceedances

Bif: bifenthrin, cyf: cyfluthrin, cyp: cypermethrin, esf: esfenvalerate, λ-cy: lambda-cyhalothrin, per: permethrin. All calculations based on whole water concentrations.

				Criteria derived by UCD method	Reduction needed to meet acute criteria derived by UCD method during exceedances		Criteria derived by EPA method	Reduction needed to meet acute criteria derived by EPA method during exceedances	
Pyrethroid	Water Body Category	Number of samples	Number of detections (%)	Number exceeding acute criterion (%)	Avg	Max	Number exceeding acute criterion (%)	Avg	Max
Bif	Ag	1,240	19 (2%)	19 (2%)	98%	100%	19 (2%)	99%	100%
	Urban	88	43 (49%)	43 (49%)	99%	100%	43 (49%)	99%	100%
	Mixed	108	23 (21%)	23 (21%)	98%	100%	23 (21%)	98%	100%
	WWTP	30	16 (53%)	16 (53%)	98%	99%	16 (53%)	98%	99%
Cyf	Ag	1,236	7 (0.6%)	7 (0.6%)	99%	99%	Not available		
	Urban	88	12 (14%)	12 (14%)	99%	100%			
	Mixed	108	7 (6%)	7 (6%)	98%	100%			
	WWTP	24	1 (4%)	1 (4%)	96%	96%			
Cyp	Ag	1,403	4 (0.3%)	4 (0.3%)	100%	100%	4 (0.3%)	100%	100%
	Urban	88	5 (6%)	5 (6%)	99%	100%	5 (6%)	95%	98%
	Mixed	108	7 (6%)	7 (6%)	99%	100%	7 (6%)	93%	100%
	WWTP	30	7 (23%)	7 (23%)	99%	100%	7 (23%)	94%	100%
Esf	Ag	1,418	24 (2%)	24 (2%)	96%	100%	Not available		
	Urban	88	0 (0%)	0 (0%)	0%	0%			
	Mixed	130	19 (15%)	18 (14%)	86%	98%			
	WWTP	18	1 (6%)	1 (6%)	95%	95%			
λ-cy	Ag	1,306	20 (2%)	20 (2%)	99%	100%	20 (2%)	95%	100%
	Urban	88	7 (8%)	7 (8%)	99%	100%	7 (8%)	94%	98%
	Mixed	108	14 (13%)	14 (13%)	98%	100%	14 (13%)	87%	99%
	WWTP	30	9 (30%)	9 (30%)	88%	99%	9 (30%)	86%	98%
Per	Ag	1,406	8 (0.6%)	7 (0.5%)	83%	99%	8 (0.6%)	82%	99%
	Urban	88	13 (15%)	10 (11%)	58%	95%	12 (14%)	65%	96%
	Mixed	108	12 (11%)	9 (8%)	48%	77%	11 (10%)	77%	98%
	WWTP	30	18 (60%)	17 (57%)	58%	87%	18 (60%)	70%	91%

Table 5-20 Reductions needed to attain chronic criteria during exceedances

Bif: bifenthrin, cyf: cyfluthrin, cyp: cypermethrin, esf: esfenvalerate, λ-cy: lambda-cyhalothrin, per: permethrin. All calculations based on whole water concentrations.

				Criteria derived by UCD method	Reduction needed to meet chronic criteria derived by UCD method during exceedances		Criteria derived by EPA method	Reduction needed to meet chronic criteria derived by EPA method during exceedances	
Pyrethroid	Water Body Category	Number of 4-day averages	Number of detections (%)	Number exceeding chronic criterion (%)	Avg	Max	Number exceeding chronic criterion (%)	Avg	Max
Bif	Ag	1,123	19 (2%)	19 (2%)	100%	100%	Not available		
	Urban	52	30 (58%)	30 (58%)	100%	100%			
	Mixed	107	22 (21%)	22 (21%)	100%	100%			
	WWTP	30	16 (53%)	16 (53%)	100%	100%			
Cyf	Ag	1,122	7 (0.6%)	7 (0.6%)	100%	100%	Not available		
	Urban	53	10 (19%)	10 (19%)	100%	100%			
	Mixed	107	6 (6%)	6 (6%)	100%	100%			
	WWTP	24	1 (4%)	1 (4%)	99%	99%			
Cyp	Ag	1,289	4 (0.3%)	4 (0.3%)	100%	100%	Not available		
	Urban	52	4 (8%)	4 (8%)	100%	100%			
	Mixed	107	6 (6%)	6 (6%)	100%	100%			
	WWTP	30	7 (23%)	7 (23%)	100%	100%			
Esf	Ag	1,292	13 (1%)	13 (1%)	91%	100%	Not available		
	Urban	52	0 (0%)	0 (0%)	0%	0%			
	Mixed	123	15 (12%)	15 (12%)	97%	100%			
	WWTP	18	1 (6%)	1 (6%)	100%	100%			
λ-cy	Ag	1,191	20 (2%)	20 (2%)	100%	100%	20 (2%)	95%	100%
	Urban	52	7 (13%)	7 (13%)	100%	100%	7 (13%)	97%	99%
	Mixed	107	13 (12%)	13 (12%)	100%	100%	13 (12%)	95%	100%
	WWTP	30	9 (30%)	9 (30%)	99%	100%	9 (30%)	94%	98%
Per	Ag	1,292	8 (0.6%)	8 (0.6%)	96%	100%	Not available		
	Urban	52	11 (21%)	11 (21%)	91%	97%			
	Mixed	107	11 (10%)	11 (10%)	86%	95%			
	WWTP	30	18 (60%)	18 (60%)	94%	100%			

If bioavailability is accounted for by comparing the freely dissolved pyrethroid concentrations to the potential water quality objectives, the necessary reductions to attain these levels in surface waters would be even smaller. In urban creeks dissolved organic carbon and particulate organic carbon levels can vary greatly. In the American River, DOC and TOC have been measured in the range of 1.04-2.61 mg/L and 1.18-3.27, respectively, whereas in Pleasant Grove Creek, DOC and TOC were measured at 10.3 mg/L and 41.1 mg/L, respectively. Peak whole water concentrations of bifenthrin and cyfluthrin have been recorded at 106 ng/L and 20 ng/L in urban watersheds (California Environmental Data Exchange Network (CEDEN) data for the time period

April 2003 through September 2013). The freely dissolved concentrations of bifenthrin and cyfluthrin were estimated for the American River and Pleasant Grove Creek using Equation 3 with the above data, summarized in Table 5-21. Particulate organic carbon (POC) was calculated as follows: POC=TOC-DOC. In this example, the freely dissolved bifenthrin and cyfluthrin concentrations in the American River would range from 10-21 ng/L and 0.9-2 ng/L, respectively. For the Pleasant Grove Creek example, freely dissolved bifenthrin and cyfluthrin concentrations would be 1 ng/L and 0.05 ng/L, respectively. In these examples the freely dissolved concentrations are 80-99% lower than the total concentrations.

Water bodies in agricultural areas require large reductions to meet any of the potential water quality objectives (Table 5-19, Table 5-20). Similar large reductions were needed to attain the chlorpyrifos and diazinon water quality objectives adopted in previous Basin Plan amendments, and excellent progress has been made on reducing the levels of those pesticides in surface waters and attaining the water quality objectives, as evidenced by completed Management Plans under the Irrigated Lands Regulatory Program and recommended de-listings (McClure et al. 2014). Based on these previous successes requiring similar large reductions in water bodies in agricultural areas, pyrethroids water quality objectives should also be reasonably achievable in these waters.

Table 5-21 Data and results of freely dissolved pyrethroid calculations for storm water examples

Parameter		Value
K_{OC} bifenthrin (L/kg)[a]		1,757,059
K_{DOC} bifenthrin (L/kg)[a]		3,550,000
C_{total} bifenthrin (ng/L)[b]		106
K_{OC} cyfluthrin (L/kg)[a]		3,389,903
K_{DOC} cyfluthrin (L/kg)[a]		8,466,659
C_{total} cyfluthrin (ng/L)[c]		20
American River low	TOC (mg/L)[d]	1.18
	DOC (mg/L)[d]	1.04
	POC (mg/L)[d]	0.14
American River high	TOC (mg/L)[e]	3.27
	DOC (mg/L)[e]	1.93
	POC (mg/L)[e]	1.34
Pleasant Grove Creek	TOC (mg/L)[f]	41.1
	DOC (mg/L)[f]	10.3
	POC (mg/L)[f]	30.8
American River low	$C_{dissolved}$ bifenthrin (ng/L)[g]	21
	$C_{dissolved}$ cyfluthrin (ng/L)[g]	2
American River high	$C_{dissolved}$ bifenthrin (ng/L)[g]	10
	$C_{dissolved}$ cyfluthrin (ng/L)[g]	0.9
Pleasant Grove Creek	$C_{dissolved}$ bifenthrin (ng/L)[g]	1
	$C_{dissolved}$ cyfluthrin (ng/L)[g]	0.05

[a]Table 5-5, [b] Data from 1/20/10 (CEDEN database), [c] Data from 10/13/09 (CEDEN database), [d]Data from 11/8/11 (CEDEN database), [e]Data from 8/4/09 (CEDEN database), [f]Data from 9/28/10 (CEDEN database), [g] Calculated using Equation 3.

For wastewater discharges, 94-100% reductions in pyrethroid levels are needed when comparing whole water pyrethroid concentrations to chronic water quality criteria (Table 5-20); however, it is likely that comparing the freely dissolved concentrations to water quality criteria would demonstrate that more moderate reductions are needed to attain the criteria levels in effluents. Parry & Young (2013) measured whole water concentrations of several pyrethroids in effluent from the Sacramento Regional Wastewater Treatment Plant, and they also calculated the freely dissolved concentrations using site-specific partition coefficients and the measured concentrations of suspended solids and DOC (analogous to Equation 3). For these samples, the freely dissolved concentrations ranged from 1-6% of the whole water concentrations. While the whole water concentrations exceed the chronic criteria derived by the UC Davis method by factors ranging from 300-100, the freely dissolved concentrations exceed these chronic criteria by factors ranging from 10-30. Although the freely dissolved concentrations still exceed the chronic criteria derived with the UC Davis method, the reductions needed to attain the criteria are much lower. While this is a small data set, this example indicates that it is likely that moderate reductions are needed meet the potential numeric water quality criteria concentrations in wastewater effluents. Additional dilution in receiving waters may also be available for some dischargers. While there are no known technologies that would result in an additional 90-97% reduction in pyrethroids in wastewater effluents, these reductions could be achievable for municipal and domestic wastewater dischargers through source control if the influent concentrations are reduced through a combination of public education and/or changes in registered pesticide uses.

Given the management practices available to dischargers and the potential or source controls to be implemented through pesticide regulatory processes, criteria with either the UC Davis or the USEPA methods both appear to be reasonably achievable for the water column, particularly if freely dissolved concentrations are used to determine attainment of the proposed water quality objectives. Because most of the criteria derived with UC Davis method are lower than those derived by the USEPA method, greater reductions are needed to attain the criteria derived by the UC Davis method. To meet the no detectable levels of pyrethroids alternative, far greater reductions would be needed, and thus more extensive implementation measures to completely prevent runoff and drift of pyrethroids.

For sediment, the no-effect level MATC alternative may be reasonably achievable if dischargers focus on reducing sediment runoff. This may be difficult for urban storm water discharges because installing sediment traps among existing developments is not always feasible. Agricultural dischargers tend to have greater flexibility in their land use and more control over their discharges. Greater changes would likely be needed to meet the no detectable levels of pyrethroids alternative. In some cases, the no detectable levels of pyrethroids could likely only be achieved through discontinuation of use or discontinuation of discharges.

It is reasonable to assume that lower water quality objectives will be more difficult to achieve and would require more resources. Some of the practices for mitigating pyrethroid impairments are more likely to be effective than others, and it is currently unknown which options will deliver the greatest reductions for the least cost and effort.

5.8.4 Economic Considerations

Agricultural Dischargers

It is likely that changes in agricultural practices will be necessary to reduce pyrethroid concentrations in the Sacramento and San Joaquin Valley water bodies. These practices and their potential costs are discussed in greater detail in sections 7 and 8.4 of this report. For the “no pyrethroids” alternative, all growers would either need to use a different pesticide product or implement measures to completely prevent surface water runoff and drift. Using an alternative to a pyrethroid would not necessarily lead to a significant increase in cost to the grower, since the cost of the actual pesticides is not a significant part of overall production costs (section 8.4), but in some cases it could increase potential pest damage by limiting pest control options available to address insecticide resistance in pests.

The costs for agricultural dischargers to attain water quality objectives were estimated as part of the Environmental Impact Report for the Long-term Irrigated Lands Regulatory Program (ICF International and CH2MHill 2010). Thus, the costs of implementing management practices that would control pyrethroid discharges are already accounted for within the overall program costs. Additional costs for monitoring pyrethroids in the water column may be incurred, but the costs of monitoring were also estimated as part of the overall program costs for agricultural dischargers. Under the Irrigated Lands Regulatory Program, monitoring requirements are determined on an annual basis and the pesticides monitored at a given site may shift from year to year as crops and pesticide use change. The water bodies in agricultural areas that are on the 303(d) List for pyrethroids are already monitored for these compounds because that is a requirement for 303(d) listings under the waste discharge requirements for this program.

The costs for agricultural dischargers directly related to attaining pyrethroid water quality objectives would likely be greatest under the “no pyrethroids” alternative because this option would require the greatest reductions of pyrethroids discharges, for either aqueous or sediment concentrations. For the water column, using criteria derived with the USEPA method would likely be less costly than the criteria derived with the UC Davis method because the UC Davis criteria are lower values. The “no change” alternative would likely have similar costs as adopting numeric objectives, depending on what the Irrigated Lands Regulatory Program uses as trigger values for pyrethroids. For sediment, the no-effect level MATC option would likely result in the similar costs directly related to attaining pyrethroids objectives as the no change in water quality objectives, because growers would still need to meet the applicable narrative objectives.

Municipal Storm Water MS4 Dischargers

Pyrethroids continue to be detected in municipal storm water discharges, but it is likely that these concentrations will decrease as a result of recent label changes on bifenthrin products and new surface water regulations promulgated by CDPR. The surface water regulations went into effect in July 2012. Conclusive monitoring results since the regulations went into effect are not yet available from CDPR; however CDPR is conducting further education and outreach, as well as enforcement, about the regulations. The bifenthrin label changes have been implemented and currently appear on bifenthrin products. If pyrethroid concentrations do not significantly decline in the water column as a result of CDPR's surface water regulations and the label changes, municipal dischargers may have costs associated with attaining numeric objectives, whether they are based on water quality criteria derived by the UC Davis or USEPA method. The proposed implementation program for municipal storm water dischargers specifies that permit compliance will be based on implementation of best management practices to the maximum extent practicable (section 7.1). All costs associated with pyrethroids water quality objectives or TMDLs will be from implementation of BMPs and pollution prevention measures and monitoring. The costs for implementation of BMPs will not vary significantly based on which water quality objective alternatives are adopted because they will be required to implement them to the maximum extent practicable regardless of what the water quality objectives are; implementation costs are discussed in section 9.1.

Municipal or Domestic Wastewater Dischargers

Pyrethroids have been detected in wastewater effluents, but have not currently been identified as a source of pyrethroids impairment in any water bodies in the Project Area. However, if numeric water quality objectives are adopted, then wastewater dischargers would be assessed for pyrethroids when their permit is renewed or adopted to determine if the effluents have reasonable potential to cause or contribute to an exceedance of the objectives. If there is reasonable potential for pyrethroids in the effluent to cause or contribute to an exceedance of the objectives, then under the proposed amendment, implementation of BMPs would be required as well as monitoring. Under this implementation approach, all costs would be associated with implementing BMPs and monitoring, which will not vary significantly based on which water quality objective alternatives are adopted. Potential costs implementation of BMPs and for monitoring are calculated in section 9.3.

5.8.5 The Need to Develop Housing

Pyrethroids are used extensively as termiticides in new home foundations, and it is not clear if these treatments are a significant source of pyrethroid runoff. These products are typically applied to the subsoil before a concrete foundation is poured. If the foundation site is not properly covered in the interim between pyrethroid application and pouring of the concrete, runoff could occur due to a storm event. Construction sites are issued National Pollution Discharge Elimination System permits and must implement measures to reduce runoff and erosion from worksites, and these same management practices would also be effective for controlling discharges of pyrethroids from housing development sites.

While pyrethroids are used in the development of new housing, the discharge of pyrethroids is not necessary for the development of new housing or to maintain existing housing supply or values, and can be avoided with implementation of BMPs that are currently required for construction sites. Therefore, none of the alternate methods for establishing water quality objectives for pyrethroids in the Sacramento and San Joaquin Valley water bodies is expected to affect housing.

5.8.6 The Need to Develop and Use Recycled Water

Pyrethroids are not known to be a limiting factor for the development or use of recycled water. Therefore, none of the alternate methods for establishing water quality objectives is expected to affect the development or use of recycled water. Decreasing pyrethroid concentrations in surface waters should improve the quality of water available for recycling. Adopting pyrethroid regulations may encourage some dischargers to recycle water to avoid discharging pyrethroids (and other pollutants) to surface waters. If pyrethroids remain in recycled water, they would not likely be problematic because the main uses for recycled water in the Central Valley, agricultural reuse and landscape and golf course irrigation (SWRCB 2011), would not likely be harmed by the expected levels of pyrethroids in recycled water.

5.8.7 Consistency of Alternate Methods with State and Federal Laws and Policies

5.8.7.1 Clean Water Act

The Clean Water Act requires that numerical criteria be based on "…(i) 304(a) Guidance; or (ii) 304(a) Guidance modified to reflect site-specific conditions; or (iii) other scientifically defensible methods" (40 C.F.R. § 131.11 (b) et seq.).

Aqueous Concentrations

Making no change in the current narrative water quality objectives would be consistent with the Clean Water Act. The Central Valley Water Board would need to interpret the existing narrative objectives to adopt TMDLs. Numeric water quality objectives based on the no pyrethroids alternative would be consistent with the Clean Water Act, since states may adopt water quality standards that are more stringent than those necessary to protect beneficial uses. Water quality objectives based on criteria derived with the UC Davis method would be consistent with the Clean Water Act, since the UC Davis methodology has protection goals consistent with the Basin Plan and Clean Water Act and these values appear to be protective of the most sensitive resident species. Water quality objectives based on criteria derived using the USEPA methodology would also be consistent with the Clean Water Act, because the protection goals of the USEPA method are what are specified in the Clean Water Act and these values appear to be protective of the most sensitive resident species.

Sediment

Making no change in the current narrative water quality objectives would be consistent with the Clean Water Act and the Central Valley Water Board would continue interpreting the existing narrative objectives to determine attainment. Numeric objectives based on the no pyrethroids alternative would be consistent with the Clean Water Act, since states may adopt water quality standards that are more stringent than those necessary to protect beneficial uses. The 304(a) guidance only applies to aqueous concentrations, so any numeric criteria for sediment concentrations would have to fall under the “other scientifically-defensible methods” category. Using an MATC for a sensitive species would be scientifically defensible as a no-effect level if the species was known to be the most sensitive resident species. *Hyalella azteca* is the most sensitive species in the sediment data sets for all six pyrethroids and is also the most sensitive known resident species in the watersheds. However, few resident species or laboratory test species have been tested, so it is possible that there could be resident species that is more sensitive to pyrethroids than *Hyalella azteca.*

5.8.7.2 Endangered Species Act

There are a number of aquatic species within the Sacramento River and San Joaquin River basins that are listed as threatened, endangered, or species of concern under the Endangered Species Act. These include the Delta smelt, Sacramento splittail, green sturgeon, steelhead trout, and multiple runs of Chinook salmon. Water quality objectives must protect the aquatic life in the Sacramento River and San Joaquin River basins, particularly endangered, threatened and endangered species and the food web and critical habitat on which they depend. Indirect effects of pyrethroids on endangered fishes could occur if populations of sensitive arthropods were reduced at critical periods when they are needed as food by juvenile fish.

Aqueous Concentrations

Water quality objectives based on the no pyrethroids alternative would provide the greatest protection. If there was no change to the water quality objectives and the narrative objectives continued to be interpreted, endangered species would be protected based on the latest technical information available. Pyrethroid water quality objectives based on the water quality criteria derived using the UC Davis method would likely be protective because threatened and endangered species were assessed in the criteria derivation. These criteria are well below available toxicity for endangered fishes, but there were no available data for endangered invertebrates or closely related surrogates, which are much more sensitive to pyrethroids than fish. The criteria derived using the USEPA method would also likely be protective of endangered species because they are consistent protective of the species based on the assessment done using the UC Davis method.

Sediment

There are no aquatic arthropods listed as threatened or endangered, but benthic invertebrates are an important part of the aquatic food web and may affect endangered fish species. Objectives based on no pyrethroids in the sediment would provide the greatest protection. The no change alternative would likely be protective because evaluation guidelines used to interpret the narrative objectives are based on data for *Hyalella azteca*, which is known to be a sensitive species compared to other aquatic organisms. Sediment bioassays are also used to assess compliance with the narrative objectives for sediment and these tests also use *Hyalella azteca*. The no-effect level MATC alternative relies on toxicity data for *Hyalella azteca*, thus if these levels are protective of this sensitive species, they are also likely protective of endangered species.

5.9 Recommended Alternative for Pyrethroid Water Quality Objectives

5.9.1 Aqueous Concentrations

The recommended water quality objectives for aqueous concentrations of pyrethroid pesticides are to use the additive concentration approach, using the water quality criteria derived with the UC Davis method as the reference values. The recommended acute water quality objective is given in Equation 7 and is for a 1-hour averaging period. The recommended chronic water quality objective is given in Equation 8 and is for a 4-day averaging period. The recommended water quality criteria to use in each of the additive water quality objectives are those derived in 2015 using the UC-Davis methodology (section 5.5.5, Table 5-7).

Equation 7

$$CNCU_{acute} = \frac{C_{bif}}{AC_{bif}} + \frac{C_{cyf}}{AC_{cyf}} + \frac{C_{cyp}}{AC_{cyp}} + \frac{C_{esf}}{AC_{esf}} + \frac{C_{lcy}}{AC_{lcy}} + \frac{C_{per}}{AC_{per}}$$

Where:
C_{bif} = Average concentration of bifenthrin from a 1-hour averaging period (ng/L),
C_{cyf} = Average concentration of cyfluthrin from a 1-hour averaging period (ng/L),
C_{cyp} = Average concentration of cypermethrin from a 1-hour averaging period (ng/L),
C_{esf} = Average concentration of esfenvalerate from a 1-hour averaging period (ng/L),
C_{lcy} = Average concentration of lambda-cyhalothrin from a 1-hour averaging period (ng/L),
C_{per} = Average concentration of permethrin from a 1-hour averaging period (ng/L),
AC_{bif} = Bifenthrin acute criterion of 0.06 ng/L,
AC_{cyf} = Cyfluthrin acute criterion of 0.07 ng/L,
AC_{cyp} = Cypermethrin acute criterion of 0.04 ng/L,
AC_{esf} = Esfenvalerate acute criterion of 0.2 ng/L,
AC_{lcy} = Lambda-cyhalothrin acute criterion of 0.03 ng/L,
AC_{per} = Permethrin acute criterion of 6 ng/L,
$CNCU_{acute}$ = Acute criteria-normalized concentration units, which is the sum of acute pyrethroid concentration-to-criterion ratios. If $CNCU_{acute}$ exceeds one (1) that indicates an exceedance of the acute additive pyrethroid pesticides water quality criterion.

Equation 8

$$CNCU_{chronic} = \frac{C_{bif}}{CC_{bif}} + \frac{C_{cyf}}{CC_{cyf}} + \frac{C_{cyp}}{CC_{cyp}} + \frac{C_{esf}}{CC_{esf}} + \frac{C_{lcy}}{CC_{lcy}} + \frac{C_{per}}{CC_{per}}$$

Where:
C_{bif} = Average concentration of bifenthrin from a 4-day averaging period (ng/L),
C_{cyf} = Average concentration of cyfluthrin from a 4-day averaging period (ng/L),
C_{cyp} = Average concentration of cypermethrin from a 4-day averaging period (ng/L),
C_{esf} = Average concentration of esfenvalerate from a 4-day averaging period (ng/L),
C_{lcy} = Average concentration of lambda-cyhalothrin from a 4-day averaging period (ng/L),
C_{per} = Average concentration of permethrin from a 4-day averaging period (ng/L),
CC_{bif} = Bifenthrin chronic criterion of 0.01 ng/L,
CC_{cyf} = Cyfluthrin chronic criterion of 0.01 ng/L,
CC_{cyp} = Cypermethrin chronic criterion of 0.01 ng/L,
CC_{esf} = Esfenvalerate chronic criterion of 0.03 ng/L,
CC_{lcy} = Lambda-cyhalothrin chronic criterion of 0.01 ng/L,
CC_{per} = Permethrin chronic criterion of 1 ng/L,
$CNCU_{chronic}$ = Chronic criteria-normalized concentration units, which is the sum of pyrethroid concentration-to-chronic criterion ratios. If $CNCU_{chronic}$ exceeds one (1) that indicates an exceedance of the chronic additive pyrethroid pesticides water quality criterion.

This additivity formula establishes a level of protection for the toxic potential of mixtures of Type I and Type II pyrethroids equivalent to the level of protection established in their individual water quality objectives. An analogous additivity formula has been established in previous TMDLs for mixtures of chlorpyrifos and diazinon. According to the Basin Plan, additivity must be considered when multiple pesticides are detected. Including the additivity formula in the water quality objectives will provide clarity and establish the same level of protection for all Sacramento River and San Joaquin River basin water bodies, regardless of whether or not they have a TMDL established.

The criteria derived by the UC Davis method are driven by toxicity studies for aquatic invertebrates and would be appropriate to use when assessing the additive toxicity of multiple pyrethroids. If the UC Davis pyrethroid criteria are adopted for use in the additive water quality objectives and new information suggests the numeric objectives are not protective enough, the Central Valley Water Board could still apply the narrative objectives to ensure protection of beneficial uses while it goes through the process of amending the numeric objectives. Currently, a number of alternative management practices are available to reduce the amount of pyrethroids introduced into the Sacramento and San Joaquin River Basin water bodies.

The “no pyrethroid” alternative is not recommended at this time as it may not be feasible to completely prevent off-site movement of pyrethroids given current allowed uses, seasons of use, and application methods. The “no change” alternative is not recommended because there is sufficient information available to establish pyrethroid water quality objectives, which will provide a clear goal for dischargers of pyrethroids. The criteria derived using USEPA method are not recommended at this time because acute and chronic criteria are not available for all six pyrethroids. While the criteria derived with the USEPA method could be used in combination with criteria from the UC Davis method, using criteria from a single method provides consistency.

As discussed in section 5.3, use of freely dissolved pyrethroid concentrations are recommended for determining attainment of the recommended water quality objectives. Methods for measuring or estimating freely dissolved concentrations are described in sections 5.3.1 and 5.3.2.

To investigate the how well the recommended water quality objectives based on freely dissolved concentrations and the additivity formulas correspond to toxicity in ambient samples, a data set with pyrethroid chemistry data and corresponding toxicity data were compared to attainment or exceedance of the recommended objectives. Because this was ambient toxicity data and toxicity identification evaluations were not performed on the samples, other constituents besides pyrethroids may have contributed or caused toxicity. However, this data set still provides some information regarding the likelihood that attainment of the recommended water quality objectives will result in concentrations unlikely to cause toxicity, and the likelihood that an exceedance may cause or contribute to toxicity.

The data set was for samples collected in the Sacramento-San Joaquin Delta from receiving waters (creeks and rivers), storm drains, agricultural drains, and wastewater treatment plant effluents (Weston and Lydy 2010). The summarized results were published and the detailed data for POC, DOC, total pyrethroid concentration, and *Hyalella azteca* toxicity results are given in Appendix C. This data set for 110 samples was used to calculate the freely dissolved pyrethroid pesticide concentrations using Equation 3 and the partition coefficients presented in Table 5-5. The freely dissolved pyrethroid concentrations were calculated and then considered additively using the acute and chronic additivity formulas given in Equation 7 and Equation 8. The criteria-normalized concentration units calculated with the additivity formulas and the estimated freely dissolved concentrations were then compared to the toxicity test results associated with the data set.

When $CNCU_{acute} \leq 1$, that would be considered attainment of the proposed acute additive objective. With this ambient data set, 85% of samples that had a $CNCU_{acute} \leq 1$ were considered not toxic (no significant difference compared to control). There were 11 samples of 75 (15%) that had a $CNCU_{acute} \leq 1$ in which toxicity was observed (significant difference compared to the control). In 7 of these 11 samples, no pyrethroids were detected. In these cases, either other constituents may have caused the toxicity, or pyrethroids may have contributed to toxicity even though they were below detection limits. In the remaining 4 samples that were toxic but had a $CNCU_{acute} \leq 1$, pyrethroids were detected and the $CNCU_{acute}$s were from 0.27, 0.46, 1.06, and 1.41. Because the $CNCU_{acute}$ is rounded to 1 significant figure, a $CNCU_{acute}$ of 1.41 is rounded to 1, and is considered attainment. When considering the entire data set, only 2 of 110 samples was classified as attaining the proposed acute objective, but had demonstrated toxicity likely caused by pyrethroids (because $CNCU_{acute} > 1.00$). Of the 35 samples that had a $CNCU_{acute} > 1$, toxicity was observed in 83% (29 samples). Of the six samples that had a $CNCU_{acute} > 1$ in which toxicity was not observed, $CNCU_{acute}$ ranged from 1.8-8.8. In these cases it is likely that less of the pyrethroids were bioavailable than were calculated with the default partition coefficients.

When $CNCU_{chronic} \leq 1$, that would be considered attainment of the proposed chronic additive objective. With this ambient data set, 89% of samples that had a $CNCU_{chronic} \leq 1$ were considered not toxic. There were 7 samples of 65 (11%) that had a $CNCU_{chronic} \leq 1$ in which toxicity was observed. Pyrethroids were not detected in any of these samples, indicating that other constituents may have caused the toxicity, or pyrethroids may have contributed to toxicity but were below detection limits. Of the 45 samples that had a $CNCU_{chronic} > 1$, toxicity was observed in 33 samples (73%). Of the 12 samples that had a $CNCU_{chronic}$ > 1 in which toxicity was not observed, $CNCU_{chronic}$ ranged from 2.4-32. In these cases it is likely that less of the pyrethroids were bioavailable than were calculated with the default partition coefficients.

The results of this limited analysis cannot conclusively demonstrate that the proposed water quality objectives are predictive of effects in the environment, this analysis does provide evidence that the combination of the water quality criteria derived by the UC Davis method, the default partition coefficients and the additivity formulas provide a reasonably accurate estimate of effects on aquatic organisms. Based on this data set, attainment or exceedance of the $CNCU_{acute}$ correlated with toxicity results in 93 of 110 samples (85%) and attainment or exceedance of the $CNCU_{chronic}$ correlated with toxicity results in 91 of 110 samples (83%). Considering these were ambient samples and other constituents may have also contributed to toxicity and the range of sorptive properties of suspended solids and DOC, these levels of agreement provide evidence the recommended water quality objectives would be reasonably protective of aquatic life.

The additivity formulas were also used with recent monitoring data compiled and analyzed for the time period April 2003 through September 2013 (California Environmental Data Exchange Network (CEDEN) database) to examine how many samples had multiple pyrethroids detected and the number of exceedances based on the additivity formulas (Table 5-22). However, for this data set, only whole water concentrations were available and the freely dissolved concentrations could not be estimated because corresponding POC and DOC data were not available.

The percentage of samples with multiple pyrethroids detected varies significantly by water body type. The incidence of multiple detections in a sample was very low for agricultural water bodies (0.4%), whereas wastewater treatment plant effluents (75%) and urban water bodies (20%) had higher incidences of multiple pyrethroids per sample. It should be noted that the sample size for agricultural water bodies is much larger than for all other water body categories and this may influence the data. However, in agricultural areas it is more likely that only one or two particular products are being used at a given time based on cropping patterns in watersheds, whereas in urban areas, the range of products used at any given time may be much larger. These differing use patterns in urban and agricultural areas may account for the higher likelihood of detecting multiple pyrethroids in a sample in urban water bodies and WWTP effluents.

In all water body categories, if pyrethroids were detected in a chronic 4-day averaging period, they always exceeded the chronic water quality criteria. For all water body types and effluents, if pyrethroids were detected in a water body, they were almost always at concentrations exceeding the proposed acute and chronic water quality objectives.

Table 5-22 Additive toxicity formula results for aqueous pyrethroids concentrations

Bif=bifenthrin, cyf=cyfluthrin, cyp=cypermethrin, esf=esfenvalerate, λ-cy=lambda-cyhalothrin, per=permethrin, CNCU=sum of pyrethroids calculated with Equation 7 and Equation 8. All data are whole water concentrations.

Type of Water Body		All Samples	**Number of Pesticide Detections**							
			Multiple Pyr	Only Bif	Only Cyf	Only Cyp	Only Esf	Only λ -cy	Only Per	None
Water Bodies in Agricultural Areas	Number of 1-hour averages	1,418	**6**	15	5	2	22	15	7	1,346
	Acute exceedances ($CNCU_{acute}$ >1)	72	**6**	15	5	2	22	15	7	0
	Number of 4-day averages	1,292	**6**	15	5	2	11	15	7	1,231
	Chronic exceedances ($CNCU_{chronic}$ >1)	61	**6**	15	5	2	11	15	7	0
	Maximum $CNCU_{acute}$	11,500	**11,500**	617	171	750	1,250	2,033	101	-
	Maximum $CNCU_{chronic}$	56,000	**56,000**	3,700	1,200	3,000	8,333	6,100	606	-
Water Bodies in Urban Areas	Number of 1-hour averages	88	**18**	26	0	0	0	0	2	42
	Acute exceedances ($CNCU_{acute}$ >1)	45	**18**	26	0	0	0	0	1	0
	Number of 4-day averages	53	**14**	12	0	0	0	0	2	25
	Chronic exceedances ($CNCU_{chronic}$ >1)	28	**14**	12	0	0	0	0	2	0
	Maximum $CNCU_{acute}$	2,133	**2,133**	1,390	0	0	0	0	4	-
	Maximum $CNCU_{chronic}$	9,277	**9,277**	6,951	0	0	0	0	27	-
Water Bodies in Areas with Mixed Urban and Agricultural Land Use	Number of 1-hour averages	130	**16**	10	0	0	11	2	2	89
	Acute exceedances ($CNCU_{acute}$>1)	41	**16**	10	0	0	11	2	2	0
	Number of 4-day averages	123	**15**	10	0	0	8	2	2	86
	Chronic exceedances ($CNCU_{chronic}$ >1)	37	**15**	10	0	0	8	2	2	0
	Maximum $CNCU_{acute}$	6,681	**6,681**	50	0	0	45	106	1.7	-
	Maximum $CNCU_{chronic}$	35,699	**35,699**	301	0	0	250	318	10	-
Municipal Wastewater Treatment Plant Effluent	Number of 1-hour averages	12	**9**	0	0	0	0	0	3	0
	Acute exceedances ($CNCU_{acute}$ >1)	12	**9**	0	0	0	0	0	3	0
	Number of 4-day averages	12	**9**	0	0	0	0	0	3	0
	Chronic exceedances ($CNCU_{chronic}$ >1)	12	**9**	0	0	0	0	0	3	0
	Maximum $CNCU_{acute}$	252	**252**	0	0	0	0	0	8	-
	Maximum $CNCU_{chronic}$	1073	**1073**	0	0	0	0	0	45	-

However, it should be noted that none of these samples accounted for bioavailability, and it is likely that some percentage of these exceedances would be below the proposed water quality objectives if the freely dissolved concentration was calculated or measured. In one study of WWTP effluents, the authors measured the freely dissolved concentrations, as well as whole water concentrations, and differentiated the fraction of pyrethroid bound to DOC, and two sizes of particulate matter (Parry and Young 2013). This study analyzed six samples from the Sacramento Regional Wastewater Treatment Plant and, in all cases, the freely dissolved pyrethroid concentrations did not exceed the acute water quality criteria, and only one of six samples exceeded the chronic criteria. In this sample set, the freely dissolved concentrations were 1-6% of the whole water concentrations.

5.9.2 Sediment Concentrations

The recommendation for sediment-associated pyrethroids is no change in water quality objectives, which means that the narrative objectives would continue to be interpreted. Based on the current science, no-effect levels in the form of MATCs for single species or numeric sediment criteria may be scientifically defensible, but are not well established for use as water quality objectives. The state of science for sediment criteria is not as well established as it is for water quality criteria, and by continuing to interpret the narrative objectives, the Central Valley Water Board will have flexibility in changing the numeric evaluation guidelines if and when values with higher certainty are available.

APPENDIX C

Ambient Data Set Comparison with Recommended Water Quality Objectives

Summarized data were published by Weston and Lydy (2010). Dr. Weston provided the detailed data including particulate organic carbon (POC), dissolved organic carbon (DOC), and whole water pyrethroid concentrations, as well as the corresponding results for each sample from 96-hour water column *Hyalella azteca* toxicity tests. The DOC data were generated by using a syringe filter in the field and the POC data were generated by taking a concurrent whole water sample and filtering through a glass fiber filter in the laboratory.

The data provided by Dr. Weston as well as the calculations of the freely dissolved pyrethroid concentrations and the acute and chronic criteria-normalized concentration units are provided in this Appendix.

Freely dissolved pyrethroid concentrations were calculated using Equation 3 and the partition coefficients for the ambient waters and wastewater treatment plant effluents given in Table 5-5. Acute and chronic criteria-normalized concentration units were calculated using Equation 7 and Equation 8 with the 2015 water quality criteria derived using the UC Davis method, given in Table 5-7.

Table C-1 Table Station information, sample date, particulate and organic carbon, and toxicity test results.

Pink highlighting on the toxicity test results indicates that the result was significantly different than the control. TSS: total suspended solids, POC: particulate organic carbon, DOC: dissolved organic carbon, %C: percentage carbon.

Source Type	Location	Sta. #	Smpl date	TSS (mg/L)	POC (mg/L)	DOC (mg/L)	%C of TSS	% mortality	% impaired
POTWs	Sacramento	SA-POTW	5/27/2008	7.7	5.643	10.840	73.3	64	72
		SA-POTW	7/15/2008	7.8	3.111	10.760	39.9	12	77
		Field dup	7/15/2008	7.3	3.322	10.380	45.5	12	72
		SA-POTW	9/22/2008	7.0	3.658	10.37	52.3	44	74
		SA-POTW	11/2/2008	20.0	2.040	11.81	10.2	40	90
		SA-POTW	2/18/2009	2.5	1.482	9.963	59.3	4	90
	Vacaville	VA-POTW	7/15/2008	1.1	1.420	10.220	129.1	2	6
		VA-POTW	9/22/2008	4.0	0.554	8.582	13.9	15	22
		VA-POTW	11/2/2008	5.0	0.711	8.519	14.2	48	64
		VA-POTW	2/16/2009	3.0	0.692	7.037	23.1	4	36
	Stockton	ST-POTW	7/15/2008	2.8	0.792	8.521	28.3	6	6
		ST-POTW	9/22/2008	4.5	0.602	7.624	13.4	5	5
		ST-POTW	1/23/2009	2.0	1.731	7.787	86.6	12	12
		ST-POTW	4/8/2009	4.6	0.964	8.342	21.0	2	2
Storm Drains	Sump 104	SA-104	7/15/2008	1.5	0.503	5.166	33.5	46	98
		SA-104	9/22/2008	2.5	0.769	4.911	30.8	40	58
		SA-104	11/1/2008	36.5	7.474	8.414	20.5	80	94
		SA-104	2/18/2009	17.6	1.456	6.549	8.3	76	98
	Sump 28	SA-28	5/27/2008	14.0	0.785	3.852	5.6	100	100
		SA-28	7/15/2008	3.0	0.365	3.569	12.2	4	8
		SA-28	9/22/2008	1.5	0.290	3.117	19.3	12	12
		SA-28	11/1/2008	182.5	8.930	9.685	4.9	72	98
		SA-28	2/18/2009	108.2	6.300	4.135	5.8	72	100
	Vacaville drn	VD	11/1/2008	165.5	4.675	6.572	2.8	74	100

		Field dup	11/1/2008	83.0	4.848	4.407	5.8	54	100
		VD	3/3/2009	14.7	2.092	2.193	14.2	66	100
	Weston Rnch	WR	5/27/2008	1.0	0.538	5.154	53.8	34	70
		Field dup	5/27/2008	1.2	0.705	8.065	58.8	54	86
		WR	7/15/2008	1.5	0.424	4.319	28.3	36	76
		WR	9/22/2008	4.5	0.930	4.509	20.7	84	100
		WR	12/15/2008	12.0	2.033	6.995	16.9	82	100
		WR	2/18/2009	66.8	1.626	3.096	2.4	28	100
	Legion Park	LP	5/27/2008	4.8	3.223	4.763	67.1	2	2
		LP	7/15/2008	7.6	1.059	5.202	13.9	2	2
		LP	9/22/2008	6.0	0.808	4.588	13.5	10	16
		LP	12/15/2008	38.0	9.914	20.04	26.1	100	100
		LP	2/18/2009	43.8	3.850	4.678	8.8	20	100
	Morada Lane	ML	5/27/2008	65.8	11.424	13.470	17.4	36	72
		ML	7/15/2008	125.0	11.868	9.026	9.5	8	66
		ML	9/22/2008	6.0	1.178	3.474	19.6	100	100
		ML	12/15/2008	26.0	2.921	7.619	11.2	90	100
		ML	2/18/2009	115.9	4.762	3.383	4.1	98	100
Ag Drains	Andrus Island	AID	5/15/2008	13.3	3.305	20.625	24.8	4	4
		AID	6/24/2008	21.7	2.584	9.638	11.9	6	6
		AID	8/4/2008	13.3	2.525	16.690	19.0	2	20
		AID	8/21/2008	18.0	2.161	12.830	12.0	0	0
		AID	2/17/2009	13.2	1.732	28.480	13.1	2	2
		AID	4/8/2009	16.5	2.189	20.120	13.3	6	6
	Empire Tract	ETD	5/15/2008	12.5	2.632	39.140	21.1	10	10
		ETD	6/24/2008	11.7	1.616	11.340	13.8	6	6
		ETD	8/4/2005	1.0	0.937	19.060	93.7	2	2
		ETD	8/21/2008	5.5	1.097	15.310	19.9	0	0
		ETD-FD	8/21/2008	6.5	0.987	15.710	15.2	0	0

	ETD	1/23/2009	10.4	2.330	24.930	22.4	4	8
	ETD	4/8/2009	14.4	2.568	28.170	17.8	2	2
Lower Roberts	LRD	5/15/2008	27.3	2.484	8.480	9.1	0	0
	LRD	6/24/2008	85.0	5.300	12.880	6.2	0	0
	LRD	8/21/2008	63.0	4.285	8.771	6.8	0	2
	LRD	1/22/2009	134.5	10.974	14.025	8.2	6	10
	LRD	2/17/2009	125.0	8.450	11.57	6.8	0	0
	LRD	4/8/2009	64.0	4.143	10.12	6.5	6	6
	LRD-FD	4/8/2009	61.0	3.927	11.14	6.4	2	4
Merritt Island	MID	5/15/2008	16.0	1.155	5.980	7.2	4	4
	MID	6/24/2008	5.3	1.898	4.268	35.8	0	0
	MID	8/21/2008	25.5	1.016	2.970	4.0	0	0
	MID	1/23/2009	18.1	0.744	4.275	4.1	8	8
	MID	2/17/2009	17.2	0.749	4.132	4.4	0	0
New Hope	NHTD	5/15/2008	38.0	1.676	3.752	4.4	4	4
	NHTD	6/24/2008	86.7	4.057	7.926	4.7	0	0
	NHTD	1/23/2009	21.8	1.597	4.752	7.3	2	10
	NHTD	2/17/2009	20.8	1.955	5.450	9.4	0	0
	NHTD	4/8/2009	24.2	4.462	6.723	18.4	2	2
Ryers Island	RID	5/15/2008	14.0	1.290	5.130	9.2	2	2
	RID	6/24/2008	16.7	1.550	4.698	9.3	2	4
	RID	8/4/2008	10.0	1.384	4.452	13.8	4	4
	RID	8/21/2008	20.5	1.710	4.460	8.3	8	8
	RID	1/23/2009	35.5	2.351	18.220	6.6	20	28
	RID	2/17/2009	47.0	2.102	16.680	4.5	12	14
Victoria Island	VID	5/15/2008	34.0	2.615	7.250	7.7	8	8
	VID	6/24/2008	99.2	6.046	9.090	6.1	0	0
	VID	8/4/2008	89.3	5.245	6.041	5.9	96	98
	VID	8/21/2008	90.0	4.900	6.058	5.4	4	4

		VID	1/23/2009	99.0	4.605	7.857	4.7	28	98
		VID	4/8/2009	68.0	6.476	7.602	9.5	6	6
	White Slough	WSD	5/15/2008	164.4	18.870	8.572	11.5	0	0
		WSD	6/24/2008	77.7	5.307	8.894	6.8	2	2
		WSD	8/4/2008	102.0	9.558	8.285	9.4	6	6
		WSD	8/21/2008	33.5	5.063	9.109	15.1	2	2
		WSD	1/23/2009	21.1	2.731	16.05	12.9	8	8
		WSD-FD	1/23/2009	19.0	2.465	17.08	13.0	4	4
		WSD	2/17/2009	76.5	7.265	13.21	9.5	2	8
Rivers	Sacramento	SA-RVR	5/27/2008	9.6	0.606	1.904	6.3	22	22
		SA-RVR	7/15/2008	25.2	0.681	1.952	2.7	4	10
		SA-RVR	9/22/2008	10.5	0.668	2.423	6.4	5	7
		SA-RVR	11/1/2008	13.0	0.331	2.013	2.5	28	30
		SA-RVR	2/16/2009	20.4	0.546	2.125	2.7	22	60
		SA-RVR	2/18/2009	184.3	3.071	3.286	1.7	10	12
		SA-RVR	3/3/2009	53.2	1.010	4.902	1.9	4	8
		SA7	2/23/2009	48.4	0.962	4.490	2.0	8	18
	American	SA4	3/3/2009	2.6	0.216	1.883	8.3	30	76
		SA4	3/18/2009	2.4	0.224	1.887	9.3	18	20
		SA5	2/23/2009	3.2	0.252	2.365	7.9	60	80
	San Joaquin	SJV	5/15/2008	34.4	1.895	7.468	5.5	0	0
		SJV	8/4/2008	70.0	2.598	3.070	3.7	4	4
		SJV	12/15/2008	10.0	0.359	2.753	3.6	2	22
		SJV	1/23/2009	31.2	0.761	2.928	2.4	18	22
		ST1	2/18/2009	17.2	0.693	3.732	4.0	4	22
		ST6	1/22/2009	3.5	0.418	4.121	11.9	14	24
	Ulatis Creek	V5	2/13/2009	27.0	1.587	2.593	5.9	16	74
	Alamo Creek	V6	2/13/2009	26.7	1.686	3.790	6.3	36	100

Table C-2 Whole water pyrethroid concentrations.
Bif: bifenthrin, lcy: lambda-cyhalothrin, esf: esfenvalerate, per: permethrin, cyf: cyfluthrin, cyp: cypermethrin.

Sta. #	Smpl date	ng/L bif	ng/L lcy	ng/L esf	ng/L per	ng/L cyf	ng/L cyp
SA-POTW	5/27/2008	2.73	0	0	0	0	0
SA-POTW	7/15/2008	0	3.48	0	12.24	0	0
Field dup	7/15/2008	0	6.42	0	14.23	0	0
SA-POTW	9/22/2008	0	0	3.69	17.17	0	0
SA-POTW	11/2/2008	0	0	0	0	0	0
SA-POTW	2/18/2009	0	0	0	9.39	0	17.03
VA-POTW	7/15/2008	3.36	2.78	0	0	0	0
VA-POTW	9/22/2008	0	0	0	0	0	0
VA-POTW	11/2/2008	0	0	0	0	0	0
VA-POTW	2/16/2009	6.26	0	0	0	0	0
ST-POTW	7/15/2008	1.41	0	0	7.88	0	0
ST-POTW	9/22/2008	0	0	0	0	0	0
ST-POTW	1/23/2009	4.76	0	0	0	0	0
ST-POTW	4/8/2009	3.97	0	0	0	0	0
SA-104	7/15/2008	1.89	0	0	0	0	2.61
SA-104	9/22/2008	3.83	0	0	0	0	0
SA-104	11/1/2008	19.9	3.27	0	0	3.12	12.33
SA-104	2/18/2009	8.38	3.13	0	10.46	0	0
SA-28	5/27/2008	2.27	6.16	0	0	0	0
SA-28	7/15/2008	1.56	0	0	0	0	0
SA-28	9/22/2008	0	0	0	0	0	0
SA-28	11/1/2008	22.37	1.05	0	14.02	3.78	10.35
SA-28	2/18/2009	3.8	1.69	0	18.36	6.87	0
VD	11/1/2008	25.46	0	0	8.98	2.41	8.45
Field dup	11/1/2008	31.46	1.84	0	31.04	4.70	5.67
VD	3/3/2009	29.77	2.61	0	25.69	11.01	0

Sta. #	Smpl date	ng/L bif	ng/L lcy	ng/L esf	ng/L per	ng/L cyf	ng/L cyp
WR	5/27/2008	3.95	0	0	1.87	0	1.23
Field dup	5/27/2008	1.96	0	0	0	0	0
WR	7/15/2008	0	0	0	0	0	0
WR	9/22/2008	0	1.96	0	5.56	3.46	0
WR	12/15/2008	0	0	0	0	10.9	0
WR	2/18/2009	25.72	2.30	0	24.99	13.97	10.71
LP	5/27/2008	1.00	0	0	0	0	0
LP	7/15/2008	0	0	0	2.41	0	0
LP	9/22/2008	3.31	0	0	1.48	0	0
LP	12/15/2008	19.13	0	0	45.77	14.46	0
LP	2/18/2009	6.73	0	0	10.22	9.56	0
ML	5/27/2008	7.76	0	0	0	0	0
ML	7/15/2008	10.46	2.08	0	7.9	3.17	4.86
ML	9/22/2008	1.30	0	0	0	0	0
ML	12/15/2008	18.42	0	0	18.52	14.97	0
ML	2/18/2009	29.63	2.78	0	30.46	7.40	7.79
AID	5/15/2008	0	0	0	0	0	0
AID	6/24/2008	0	0	0	0	0	0
AID	8/4/2008	0	0	0	0	0	0
AID	8/21/2008	0	0	0	0	0	0
AID	2/17/2009	5.84	0	0	0	0	0
AID	4/8/2009	0	0	0	0	0	0
ETD	5/15/2008	0	0	0	0	0	0
ETD	6/24/2008	0	0	0	0	0	0
ETD	8/4/2005	0	0	0	0	0	0
ETD	8/21/2008	0	0	0	0	0	0
ETD-FD	8/21/2008	0	0	0	0	0	0
ETD	1/23/2009	0	0	0	0	0	0

Sta. #	Smpl date	ng/L bif	ng/L lcy	ng/L esf	ng/L per	ng/L cyf	ng/L cyp
ETD	4/8/2009	0	0	0	0	0	0
LRD	5/15/2008	0	0	0	0	0	0
LRD	6/24/2008	1.36	0	0	0	0	0
LRD	8/21/2008	0	0	0	0	0	0
LRD	1/22/2009	0	0	0	0	0	0
LRD	2/17/2009	1.7	0	0	0	0	0
LRD	4/8/2009	0	0	0	0	0	0
LRD-FD	4/8/2009	0	0	0	0	0	0
MID	5/15/2008	0	0	0	0	0	0
MID	6/24/2008	0	0	0	0	0	0
MID	8/21/2008	0	0	0	0	0	0
MID	1/23/2009	0	0	0	0	0	0
MID	2/17/2009	0	0	0	0	0	0
NHTD	5/15/2008	0	0	0	0	0	0
NHTD	6/24/2008	0	0	0	0	0	0
NHTD	1/23/2009	0	0	0	0	0	0
NHTD	2/17/2009	0	0	0	0	0	0
NHTD	4/8/2009	0	0	0	0	0	0
RID	5/15/2008	0	0	0	0	0	0
RID	6/24/2008	0	0	0	0	0	0
RID	8/4/2008	0	0	0	0	0	0
RID	8/21/2008	0	0	0	0	0	0
RID	1/23/2009	0	0	0	0	0	0
RID	2/17/2009	0	0	0	0	0	0
VID	5/15/2008	0	0	0	0	0	0
VID	6/24/2008	0	0	0	0	0	0
VID	8/4/2008	0	17.46	1.1	0	0	0
VID	8/21/2008	0	0	0	0	0	0

Sta. #	Smpl date	ng/L bif	ng/L lcy	ng/L esf	ng/L per	ng/L cyf	ng/L cyp
VID	1/23/2009	0	3.18	0	0	0	0
VID	4/8/2009	0	0	0	0	0	0
WSD	5/15/2008	0	0	0	0	0	0
WSD	6/24/2008	0	0	0	0	0	0
WSD	8/4/2008	0	0	5.14	0	0	0
WSD	8/21/2008	0	0	0	0	0	0
WSD	1/23/2009	0	0	0	0	0	0
WSD-FD	1/23/2009	0	0	0	0	0	0
WSD	2/17/2009	3.01	0	0	0	0	0
SA-RVR	5/27/2008	0	0	0	0	0	0
SA-RVR	7/15/2008	1.37	0	0	0	0	0
SA-RVR	9/22/2008	0	0	0	0	0	0
SA-RVR	11/1/2008	0	0	0	0	0	0
SA-RVR	2/16/2009	0	0	0	0	0	0
SA-RVR	2/18/2009	2.71	0	0	0	0	0
SA-RVR	3/3/2009	0	0	0	0	0	0
SA7	2/23/2009	0	0	0	0	0	0
SA4	3/3/2009	0	0	0	0	0	0
SA4	3/18/2009	0	0	0	0	0	0
SA5	2/23/2009	0	0	0	0	0	0
SJV	5/15/2008	0	0	0	0	0	0
SJV	8/4/2008	0	0	0	0	0	0
SJV	12/15/2008	0	0	0	0	0	0
SJV	1/23/2009	0	0	0	0	0	0
ST1	2/18/2009	0	0	0	9.18	0	0
ST6	1/22/2009	0	0	0	0	0	0
V5	2/13/2009	10.44	2.19	0	2.49	0	0
V6	2/13/2009	17.92	0	0	5.95	6.56	0

Table C-3 Freely dissolved pyrethroid concentrations (ng/L) and the acute and chronic criteria-normalized concentration units (CNCU).

C_{diss}: Estimated freely dissolved concentration, bif: bifenthrin, lcy: lambda-cyhalothrin, esf: esfenvalerate, per: permethrin, cyf: cyfluthrin, cyp: cypermethrin.

Sta. #	Smpl date	C_{diss} bif	C_{diss} lcy	C_{diss} esf	C_{diss} per	C_{diss} cyf	C_{diss} cyp	$CNCU_{acute}$	$CNCU_{chronic}$
SA-POTW	5/27/2008	0.03	0.00	0.00	0.00	0.00	0.00	2.75	2.75
SA-POTW	7/15/2008	0.00	0.14	0.00	0.36	0.00	0.00	14.10	14.10
Field dup	7/15/2008	0.00	0.24	0.00	0.39	0.00	0.00	24.39	24.39
SA-POTW	9/22/2008	0.00	0.00	0.02	0.43	0.00	0.00	1.76	1.76
SA-POTW	11/2/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA-POTW	2/18/2009	0.00	0.00	0.00	0.53	0.00	1.38	138.50	138.50
VA-POTW	7/15/2008	0.11	0.21	0.00	0.00	0.00	0.00	31.72	31.72
VA-POTW	9/22/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
VA-POTW	11/2/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
VA-POTW	2/16/2009	0.36	0.00	0.00	0.00	0.00	0.00	35.57	35.57
ST-POTW	7/15/2008	0.07	0.00	0.00	0.74	0.00	0.00	7.66	7.66
ST-POTW	9/22/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ST-POTW	1/23/2009	0.14	0.00	0.00	0.00	0.00	0.00	13.73	13.73
ST-POTW	4/8/2009	0.17	0.00	0.00	0.00	0.00	0.00	17.30	17.30
SA-104	7/15/2008	0.09	0.00	0.00	0.00	0.00	0.31	40.69	40.69
SA-104	9/22/2008	0.19	0.00	0.00	0.00	0.00	0.00	19.36	19.36
SA-104	11/1/2008	0.45	0.05	0.00	0.00	0.03	0.40	92.68	92.68
SA-104	2/18/2009	0.31	0.07	0.00	0.15	0.00	0.00	38.13	38.13
SA-28	5/27/2008	0.14	0.22	0.00	0.00	0.00	0.00	36.41	36.41
SA-28	7/15/2008	0.11	0.00	0.00	0.00	0.00	0.00	10.90	10.90
SA-28	9/22/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA-28	11/1/2008	0.44	0.01	0.00	0.11	0.03	0.28	76.86	76.86
SA-28	2/18/2009	0.14	0.04	0.00	0.28	0.12	0.00	30.57	30.57
VD	11/1/2008	0.78	0.00	0.00	0.11	0.03	0.40	121.29	121.29

Sta. #	Smpl date	C_{diss} bif	C_{diss} lcy	C_{diss} esf	C_{diss} per	C_{diss} cyf	C_{diss} cyp	$CNCU_{acute}$	$CNCU_{chronic}$
Field dup	11/1/2008	1.25	0.05	0.00	0.49	0.09	0.29	168.10	168.10
VD	3/3/2009	2.39	0.13	0.00	0.84	0.41	0.00	294.33	294.33
WR	5/27/2008	0.20	0.00	0.00	0.04	0.00	0.15	34.18	34.18
Field dup	5/27/2008	0.06	0.00	0.00	0.00	0.00	0.00	6.35	6.35
WR	7/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WR	9/22/2008	0.00	0.06	0.00	0.12	0.08	0.00	14.37	14.37
WR	12/15/2008	0.00	0.00	0.00	0.00	0.16	0.00	16.24	16.24
WR	2/18/2009	1.73	0.09	0.00	0.67	0.43	1.19	344.92	344.92
LP	5/27/2008	0.04	0.00	0.00	0.00	0.00	0.00	4.24	4.24
LP	7/15/2008	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.04
LP	9/22/2008	0.18	0.00	0.00	0.03	0.00	0.00	17.73	17.73
LP	12/15/2008	0.21	0.00	0.00	0.20	0.07	0.00	28.63	28.63
LP	2/18/2009	0.28	0.00	0.00	0.17	0.18	0.00	45.60	45.60
ML	5/27/2008	0.11	0.00	0.00	0.00	0.00	0.00	11.26	11.26
ML	7/15/2008	0.19	0.02	0.00	0.06	0.03	0.11	35.72	35.72
ML	9/22/2008	0.08	0.00	0.00	0.00	0.00	0.00	8.44	8.44
ML	12/15/2008	0.56	0.00	0.00	0.21	0.20	0.00	75.58	75.58
ML	2/18/2009	1.39	0.08	0.00	0.57	0.16	0.44	207.33	207.33
AID	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
AID	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
AID	8/4/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
AID	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
AID	2/17/2009	0.06	0.00	0.00	0.00	0.00	0.00	5.55	5.55
AID	4/8/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ETD	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ETD	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ETD	8/4/2005	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ETD	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0

Sta. #	Smpl date	C_{diss} bif	C_{diss} lcy	C_{diss} esf	C_{diss} per	C_{diss} cyf	C_{diss} cyp	$CNCU_{acute}$	$CNCU_{chronic}$
ETD-FD	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ETD	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ETD	4/8/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
LRD	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
LRD	6/24/2008	0.02	0.00	0.00	0.00	0.00	0.00	2.43	2.43
LRD	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
LRD	1/22/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
LRD	2/17/2009	0.03	0.00	0.00	0.00	0.00	0.00	2.99	2.99
LRD	4/8/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
LRD-FD	4/8/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
MID	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
MID	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
MID	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
MID	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
MID	2/17/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
NHTD	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
NHTD	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
NHTD	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
NHTD	2/17/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
NHTD	4/8/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
RID	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
RID	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
RID	8/4/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
RID	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
RID	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
RID	2/17/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
VID	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
VID	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0

Sta. #	Smpl date	C_{diss} bif	C_{diss} lcy	C_{diss} esf	C_{diss} per	C_{diss} cyf	C_{diss} cyp	$CNCU_{acute}$	$CNCU_{chronic}$
VID	8/4/2008	0.00	0.34	0.01	0.00	0.00	0.00	34.33	34.33
VID	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
VID	1/23/2009	0.00	0.05	0.00	0.00	0.00	0.00	5.15	5.15
VID	4/8/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WSD	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WSD	6/24/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WSD	8/4/2008	0.00	0.00	0.02	0.00	0.00	0.00	0.71	0.71
WSD	8/21/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WSD	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WSD-FD	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
WSD	2/17/2009	0.05	0.00	0.00	0.00	0.00	0.00	4.96	4.96
SA-RVR	5/27/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA-RVR	7/15/2008	0.15	0.00	0.00	0.00	0.00	0.00	15.01	15.01
SA-RVR	9/22/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA-RVR	11/1/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA-RVR	2/16/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA-RVR	2/18/2009	0.15	0.00	0.00	0.00	0.00	0.00	15.00	15.00
SA-RVR	3/3/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA7	2/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA4	3/3/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA4	3/18/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SA5	2/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SJV	5/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SJV	8/4/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SJV	12/15/2008	0.00	0.00	0.00	0.00	0.00	0.00	0	0
SJV	1/23/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0
ST1	2/18/2009	0.00	0.00	0.00	0.23	0.00	0.00	0.23	0.23
ST6	1/22/2009	0.00	0.00	0.00	0.00	0.00	0.00	0	0

Sta. #	Smpl date	C_{diss} bif	C_{diss} lcy	C_{diss} esf	C_{diss} per	C_{diss} cyf	C_{diss} cyp	$CNCU_{acute}$	$CNCU_{chronic}$
V5	2/13/2009	0.80	0.10	0.00	0.08	0.00	0.00	90.77	90.77
V6	2/13/2009	1.03	0.00	0.00	0.13	0.17	0.00	119.93	119.93

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